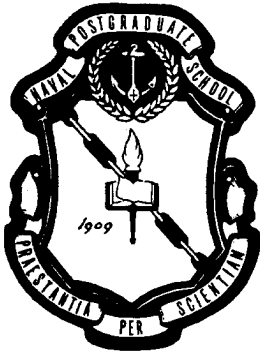


Naval Postgraduate School
Monterey, California 93943-5138



SUMMARY OF RESEARCH 1997

Interdisciplinary Academic Groups

C3 - Dan C. Boger, Chair

Information Warfare - Fred Levien, Chair

Space Systems - Rudolf Panholzer, Chair

Undersea Warfare - James Eagle, Chair

**Ching-Sang Chiu
Associate Chair for Research**

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

19990304 084

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral R.C. Chaplain
Superintendent

R. Elster
Provost

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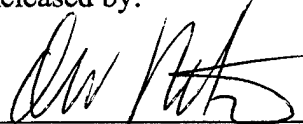
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REPORT DOCUMENTATION PAGE

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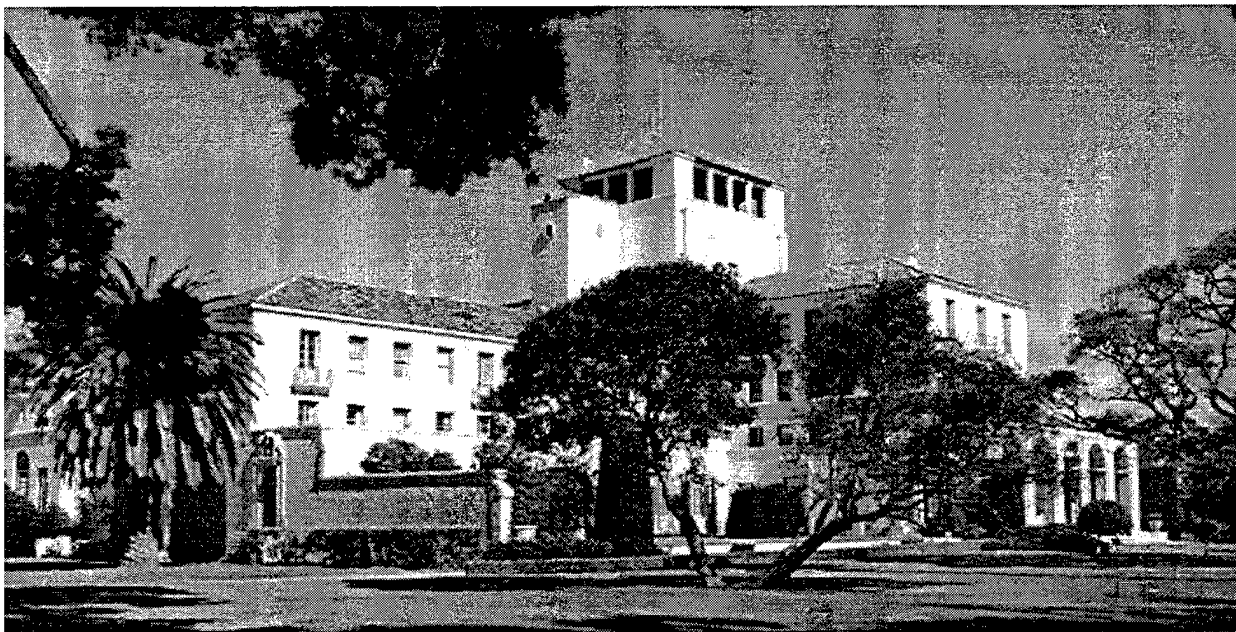
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THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges



CONTENTS

Preface	7
Introduction	9
Command, Control, and Communications	13
Faculty	15
Group Summary	17
Project Summaries	21
Adaptive Architectures for Command and Control (A2C2)	22
Adaptive Coordination for Flexible C3 Organizations	24
Analytical Support for Convectional Ammunition Program	22
Command, Control, and Communication (C3) Analysis Techniques	23
Concepts for C4ISR and Information Superiority in Humanitarian Assistance/Disaster Relief (HA/DR Operations)	25
Human Centered Design Tools	22
Joint Command, Control, and Communications Chair Professorship	23
Naval Postgraduate School Support to JWID 97	23
Leading Edge Services Collaborative Applications Team	21
Near-Real-Time Mission Updates Via the Global Broadcasting System (GBS)	21
Research on Global Broadcast System (GBS) Services	24
Simulation of Expeditionary Warfare	25
SC-21 Consulting Support	23
Tactical Decision Making Under Stress	21
Targeting Sub-State Political Groups	24
Thesis Support for the Operational Support Office	21
Thesis Abstracts	27
Information Warfare	39
Faculty	41
Group Summary	43
Project Summaries	45
Chinese Budgetary and Defense Planning Priorities	45
Curriculum Development in Tactics, Doctrine, and Operational Analysis	47
Independent Technical Analysis of Fleet ASCM Training Simulator	49
Information Operations Modeling and Simulation (IO M&S)	45
Information Warfare Applied to the Joint C2W Attack Mission	48
Investigation of Hard-Kill - Soft-Kill Interactions	48
NPS Network Research Lab	46
Strategic Framework for Information Warfare: Task 4, The Development of Information Strategy	45
Wideband Digital Compressive Receivers	47
Publications and Presentations	51
Thesis Abstracts	53

Space Systems	59
Faculty	61
Group Summary	63
Project Summaries	65
A Novel Technique for Search and Geolocation of Signals From Low-Earth Orbit	65
Center for Research Into the Military Applications of Space	70
Ferroelectricity Research Newsletter	69
Naval Space Systems Academic Chair	69
Near-Earth-Object Interception	70
Project Gusty Oriole, Computer Algorithms and Architectures for Space Applications	66
Radiation Hardening of Space-Based Electronic Devices and Solar Cells	67
Spacecraft Design Instruction and Research Support	69
Space Operations Experience Tours	68
Spacecraft Systems	65
Space Systems Students Thesis Research Projects	68
Theater Ballistic Missile Defense-Multi-Sensor Fusion, Tracking, and Targeting Techniques	66
Publications and Presentations	71
Thesis Abstracts	73
Undersea Warfare	77
Faculty	79
Group Summary	81
Project Summaries	83
Autonomous Underwater Vehicle (AUV) Development	83
Data Analysis for the SWARM Experiment	85
Development of the Pt. Sur Ocean Acoustic Observatory	89
International Conference in Shallow-Water Acoustics	88
Middle Atlantic Bight (Shelfbreak Primer) Field Study	86
Monitoring Whales Using the Pt. Sur Acoustic Array - A Feasibility Study	87
Rapidly Reconfigurable Virtual Environment Network Protocols	84
Submarine Security	90
Surf Zone Seismo Acoustics	90
Tactical Visualization of the Environment: Manta Minefield Search	83
Publications and Presentations	93
Thesis Abstracts	95
Initial Distribution List	99

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, four interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Academic Groups (Command, Control, and Communications, Information Warfare, Space Systems, and Undersea Warfare) during 1997. Also included is an overview of each academic group, faculty listings, compilations of publications/presentations, and abstracts from theses directed by the academic groups faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed or the Academic Group Chair. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2098 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil~code09/>.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- **Reimbursable (Sponsored) Program:** This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.
- **NPS Institutionally Funded Research Program (NIFR):** The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.
- **Institute for Joint Warfare Analysis (IJWA) Program:** The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1997, the overall level of research effort at NPS was 151 faculty workyears and exceeded \$32 million. The Academic Groups' effort was 8.15 faculty workyears and exceeded \$3 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY97, over 87% percent of the NPS research program was externally supported. In the Academic Groups 97% was externally supported.

Research sponsorship in FY97 for the Command, Control, and Communications Academic Group is provided in Figure 1, Information Warfare Academic Group in Figure 2, Space Systems Academic Group in Figure 3, and Undersea Warfare Academic Group in Figure 4.

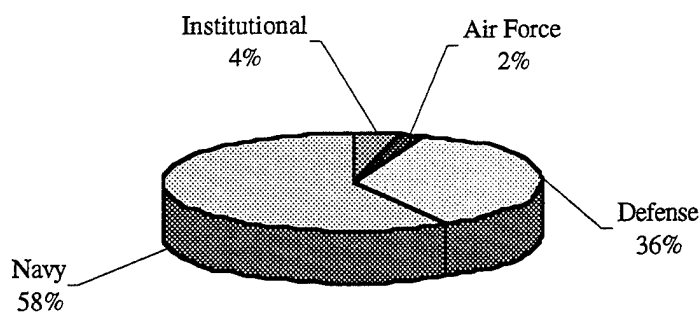


Figure 1. FY97 Sponsor Profile of the Command, Control, and Communications Academic Group

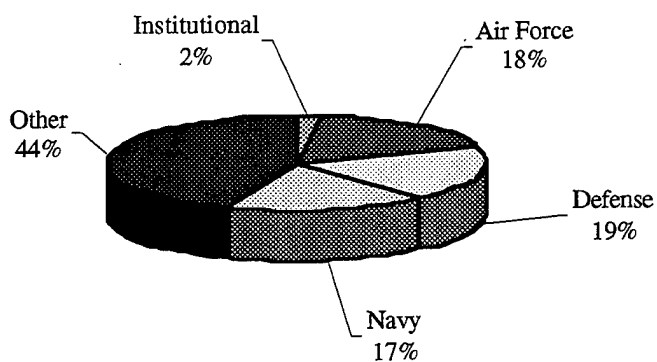


Figure 2. FY97 Sponsor Profile of the Information Warfare Academic Group

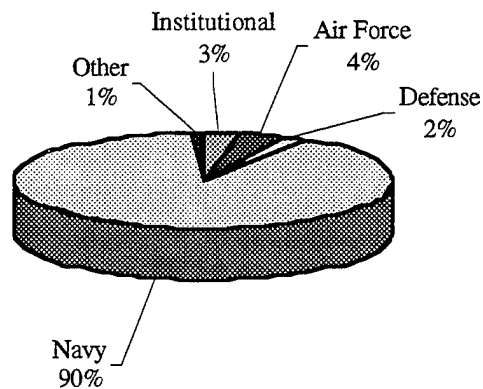


Figure 3. FY97 Sponsor Profile of the Space Systems Academic Group

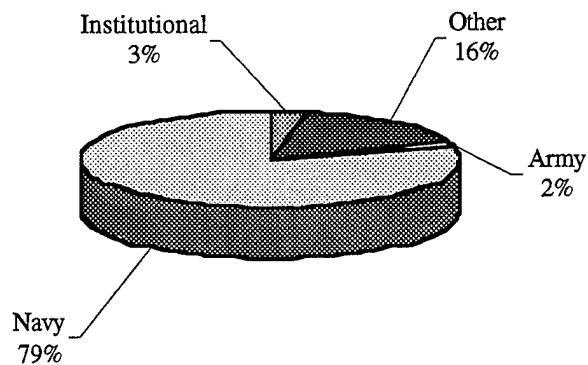


Figure 4. FY97 Sponsor Profile of the Undersea Warfare Academic Group

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

January 1999

**COMMAND, CONTROL,
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GROUP SUMMARY CC

The Command, Control, and Communications (C3) Academic Group is an interdisciplinary association of faculty which consists of 25 faculty members who hold appointments in 9 departments/groups at the Naval Postgraduate School, plus the Curricular Officer. The C3 Academic Group has responsibility for the academic content of the Joint Command, Control, Communications, Computers, and Intelligence Systems curriculum and the Scientific and Technical Intelligence curriculum. C3 Academic Group faculty members carry out research in C4I systems, broadly defined, to support these two curricula.

During 1997, the C3AG consisted of the following members:

Lieutenant Colonel Michael Mullady, USAF, Curricular Officer
Professor Dan C. Boger (Command, Control and Communications), Chair
Lecturer Rex A. Buddenberg (Systems Management)
Professor Ralph N. Channel (National Security Affairs)
Professor Kenneth L. Davidson (Meteorology)
Professor Donald P. Gaver (Operations Research)
Lieutenant Colonel John Gibson, USAF (Command, Control and Communications)
Senior Lecturer Wayne P. Hughes (Operations Research)
Lieutenant Commander Steven J. Iatrou, USN (Information Warfare)
Professor Carl R. Jones (Systems Management)
Associate Professor William G. Kemple (Command, Control and Communications)
Professor Herschel H. Loomis (Electrical and Computer Engineering)
Professor Orin E. Marvel (Command, Control and Communications)
Associate Professor Gordon McCormick (Command, Control and Communications)
Associate Professor Paul H. Moose (Electrical and Computer Engineering)
Associate Professor John S. Osmundson (Command, Control and Communications)
Professor Patrick J. Parker (Command, Control and Communications)
Associate Professor Gary R. Porter (Command, Control and Communications)
Associate Professor Craig Rasmussen (Mathematics)
Professor Nancy C. Roberts (Systems Management)
Associate Professor Timothy J. Shimeall (Computer Science)
Professor Michael G. Sovereign (Command, Control and Communications)
Associate Professor Donald v.Z. Wadsworth (Electrical and Computer Engineering)

An overview of the Command, Control, and Communications (C3) Academic Group research program follows.

Thesis Support for the Operational Support Office

Dan Boger continued his research with NPS thesis students into the potential benefits to the Joint Task Force Commander for real-time command and control of warfighting forces through the direct downlinking of information from sensors. By examining specific JTF-level scenarios, several alternative concepts of operation for directly-linked sensor information are compared to current, existing sensor information architectures. Measures of effectiveness focus on the tradeoff of latency for quality of information. Scenarios involving both generic command and control as well as targeting-quality information for specific weapons systems are being evaluated.

Support for TADMUS Experiments and Data Analysis

Research Psychologist Susan Hutchins continued research support to the Tactical Decision Making Under Stress (TADMUS) Program, sponsored by Office of Naval Research. The objective of the TADMUS program is to apply recent developments in decision theory, individual and team training, and information display to the problem of enhancing tactical decision quality under conditions of stress. The specific research support in this project is being provided to Naval Command

GROUP SUMMARY CC

Control Communications and Ocean Surveillance Center Research and Redevelopment Division (NRaD), where the experiments are being conducted, and this support includes a decision support system, training strategies, and alternative human-machine interface concepts. Experimentation using specific anti-air scenarios is used to assess the effectiveness of the newly developed decision support system.

Adaptive Architectures for Command and Control

William Kemple and Michael Sovereign contributed to a four-year, continuing project whose objectives are to: extend twelve years of Navy decision-making research into the joint C2 arena; expand the domain beyond the frequently studied anti-air warfare arena; focus on adaptive architectures; and produce results ranging from purely theoretical to those that can be used by the operational forces in the near term. This project is the NPS portion of a government, industry, academe team formed by Office of Naval Research to carry out this program.

Command, Control, and Communications (C3) Analysis Techniques

William Kemple continued an on-going research project whose main objective is to identify research topics of current interest to the Marine Corps and match thesis students with these topics. Emphasis is on measuring C3 systems effectiveness and identifying futuristic C3 technologies which, if developed and implemented, might enhance MAGTF C3 capabilities and support the new Marine Corps Operational Maneuvers from the Sea (OMFTS) and Operation Other Than War (OOTW) concepts.

Support for the Joint C4I Chair Professorship

Orin Marvel, the holder of the Joint C4I Chair Professorship sponsored by the Defense Information Systems Agency, continued his research in systems engineering for C4I systems and theater missile defense. He also continued his support of the Joint C4I Systems curriculum through further development of systems engineering projects and courses.

Targeting Underground Organizations

Gordon McCormick and Guillermo Owen, Department of Mathematics, developed a formal framework for evaluating the dynamics of sub-state conflict and used this framework to examine ways in which to improve our ability to target terrorist organizations.

Special Operations/Low Intensity Conflict (SO/LIC) Curriculum Teaching and Research Support

Gordon McCormick continued his project which provides instructional and research support to the students and faculty of the Special Operations Curriculum.

Command and Control of Underground Organizations

Gordon McCormick examined the functions, methods, and structures of underground systems of command and control. Specific examples are analyzed as cases.

GROUP SUMMARY CC

Global Broadcast System Testbed

Paul Moose began procuring equipment to support the installation of a downlink testbed for the Global Broadcast System (GBS) in the NPS System Technology Laboratory (STL).

PROJECT SUMMARIES CC

LEADING EDGE SERVICES COLLABORATIVE APPLICATIONS TEAM

Dan C. Boger, Professor

Command, Control, and Communications Academic Group

Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: This proposal covers projects by a collaborative team of researchers and students which utilize the capabilities of the DARPA/DISN leading edge services network and the Naval Postgraduate School technology laboratory.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Networking, Communications, Databases, Concepts of Operation

THESIS SUPPORT FOR THE OPERATIONAL SUPPORT OFFICE

Dan C. Boger, Professor

Command, Control, and Communications Academic Group

Sponsor: Secretary of the Air Force

OBJECTIVE: This proposal covers projects which will be carried out by master's thesis students in a variety of curricula at NPS which will focus on improving information support to the Joint Force Commander.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Concepts of Operation, Databases, Communications, Networking, Sensors

NEAR-REAL-TIME MISSION UPDATES VIA THE GLOBAL BROADCASTING SYSTEM (GBS)

Dan C. Boger, Professor

Command, Control, and Communications Academic Group

Sponsor: Naval Engineering Logistics Office

OBJECTIVE: Perform proof-of-concept of potential scenario simulation and data/video transmission via GBS of Near-Real-Time mission updates for quick reaction teams utilizing the capabilities of the Naval Postgraduate School's Systems Technology Laboratory.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Networking, Communications, Databases, Concepts of Operation

TACTICAL DECISION MAKING UNDER STRESS

Susan Hutchins, Research Assistant

Command, Control, and Communications Academic Group

Sponsor: Space and Naval Warfare Systems Center--San Diego

OBJECTIVE: The objective of the TADMUS program is to apply recent developments in decision theory, individual and team training, and information display to the problem of enhancing tactical decision quality under conditions of stress. Products of this research will include a decision support system (DSS) and general principles for advanced decision support systems, a variety of training strategies that will attenuate the effects of stress on team performance, and human-system interaction concepts which maximize the effectiveness of tactical decision aids under stressful conditions; general principles will be developed that will be applicable to other warfare areas. Experimentation is required to assess the effectiveness of the newly developed decision support system.

PROJECT SUMMARIES CC

DoD KEY TECHNOLOGY AREA: Human System Interfaces

KEYWORDS: Human Factors, Decision Theory, C3, Decision Support System, Human System interface

HUMAN CENTERED DESIGN TOOLS

Susan Hutchins, Research Assistant

Command, Control, and Communications Academic Group

Sponsor: Naval Submarine Medical Research Lab

OBJECTIVE: The objectives of this project are to define the behavioral components of the command, information and control (CIC) suite (e.g., Cognitive tasks and decision making, review, refine or develop effective assessment instruments of human system performance in the CIC, apply existing and new models of the CIC with the purpose of enhancing efficiency and reliability while reducing manning through automation, review existing system design processes with respect to determining the utilization of humans and human systems interfaces, define a human-centered design tool interface that incorporates the results to improve the process of designing complex systems.

DoD KEY TECHNOLOGY AREA: Human System Interface

KEYWORDS: Human Factors, Automation, Decision Theory, Command and Control, Decision Support System

ANALYTICAL SUPPORT FOR CONVECTIONAL AMMUNITION PROGRAM

William Kemple, Associate Professor

Command, Control, and Communications Academic Group

Sponsor: Naval Surface Warfare Center-Crane Division

OBJECTIVE: To provide analyst support to convectional ammunition program office by implementing NSFS, AAW and ASuW architectures in the Naval Simulation System (NSS). Support will include the developing data sources, devising documentation methods, creating input databases, and performing analyses in support of program review 1999 (PR99).

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Assessment

ADAPTIVE ARCHITECTURES FOR COMMAND AND CONTROL (A2C2)

William Kemple, Associate Professor

Command, Control, and Communications Academic Group

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To gain insight into the issues of adaptation in joint C2 architectures. To develop theories of C2, i.e., "Congruence" of task and organization. To use modeling to identify near-optimal organizational decisions for CS tasks. To test the theories and models in a series of experiments. To support implementation of adaptable C2 architectures.

DoD KEY TECHNOLOGY AREA: Human System Interfaces

KEYWORDS: Command and Control, Joint Operations, Organizational Experiments

PROJECT SUMMARIES CC

COMMAND, CONTROL AND COMMUNICATION (C3) ANALYSIS TECHNIQUES

William Kemple, Associate Professor

Command, Control, and Communications Academic Group

Sponsor: U.S. Marine Corps Systems Command

OBJECTIVE: To continue research in support of the Marine Corps concept based requirements system and the combat development process by identifying and developing a set of SPATIO-Temporal measures of combat potential appropriate for the MAGTF commander. Implementing a selected subset of the measures as dynamic displays of MTWS. Conducting a small experiment using officer students as commanders to assess the utility of the displays. Examining other mutually agreed upon issues of interest to the Marine Corps concept based requirements system and the combat development process.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Command, Control, and Communications, MOES, Combat Potential

NAVAL POSTGRADUATE SCHOOL SUPPORT TO JWID 97

William Kemple, Associate Professor

Command, Control, and Communications Academic Group

Sponsors: Space and Naval Warfare Systems Command

OBJECTIVE: Provide support to the U.S. Navy JWID 97 program office. Tasks include assisting in the assessment of JWID 97 demonstrations and providing input into the JWID 97 final report.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: C4I System Evaluation, and C4I MOE'S

JOINT COMMAND, CONTROL, AND COMMUNICATIONS CHAIR PROFESSORSHIP

Orin C. Marvel, Visiting Associate Professor

Command, Control, and Communications Academic Group

Sponsor: Defense Information Systems Agency

OBJECTIVE: The Joint C3 Chair Professorship is established to provide conceptual, intellectual and practical expertise to the joint C4I systems students in C4I systems and systems engineering. These duties will include teaching, advising, thesis reading, and laboratory research. The objective shall be to improve the students understanding of command and control techniques, systems, doctrine, personnel, missions, requirements, technologies and systems engineering processes.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Command, Control, and Communications, Doctrine, Intelligence

SC-21 CONSULTING SUPPORT

Orin C. Marvel, Visiting Associate Professor

Command, Control, and Communications Academic Group

Sponsor: Naval Sea Systems Command

OBJECTIVE: Perform consulting support and analysis of the human control interface on board a defined SC-21. Coordinate activities with CSACT and ADCOM-21 developments.

PROJECT SUMMARIES CC

DoD KEY TECHNOLOGY AREA: Human Systems Interface

KEYWORDS: SC-21, Human Control Interface

TARGETING SUB-STATE POLITICAL GROUPS

Gordon McCormick, Associate Professor

Command, Control, and Communications Academic Group

Guillermo Owen, Professor

Department of Mathematics

Sponsor: Office of the Secretary of Defense

OBJECTIVE: To develop a rigorous framework for evaluating the dynamics of sub-state political conflict and use this framework to examine the ways in which we might improve our ability to deter, compel, and if necessary, target sub-state groups.

DoD KEY TECHNOLOGY AREA: Other (Sub-State Political Conflict)

KEYWORDS: Sub-State Conflict

RESEARCH ON GLOBAL BROADCAST SYSTEM (GBS) SERVICES

Paul Moose, Associate Professor

Command, Control, and Communications Academic Group

Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: A receive site GBS test bed will be completed in the NPS systems technology laboratory. This will be used to conduct experimental research on critical technical and functional aspects of the GBS service. This year, the research will focus on low cost technology for providing a variable bit rate GBS service to mobile and deploying users.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Global Broadcast Service, Satellite Communications

ADAPTIVE COORDINATION FOR FLEXIBLE C3 ORGANIZATIONS

Michael Sovereign, Professor

Command, Control, and Communications Academic Group

Sponsor: Office of Naval Research

OBJECTIVE: This cost proposal covers the NPS portion of the work of the proposal entitled adaptive coordination for C3 flexible organizations. It follows the standard NPS format and cost categories. The NPS portion of the proposed work focuses on tasks 3,4, and 5 described in the companion alphatech-UCONN-NPS Combined technical and management proposal P3800-123. NPS is most extensively involved in the empirical portion of the proposal although all portions are integrated to a considerable extent.

DoD KEY TECHNOLOGY AREA: Human System Interfaces

KEYWORDS: Command and Control, Joint Operations, Organizational Experiments

PROJECT SUMMARIES CC

SIMULATION OF EXPEDITIONARY WARFARE

Michael Sovereign, Professor

Command, Control, and Communications Academic Group

Sponsor: Office of the Secretary of Defense

OBJECTIVE: This proposal initiates a research program to identify simulations that can be adapted to addressing the issues of expeditionary warfare and demonstrating their use in wargaming, tactical development and technology requirements. These simulations will allow the easy visualization of the underlying detailed physical dynamics, lines of sight, coordination of fires, maneuver and logistics upon which these concepts will ultimately depend.

DoD KEY TECHNOLOGY AREA: Other (Wargaming)

KEYWORD: Expeditionary Warfare

CONCEPTS FOR C4ISR AND INFORMATION SUPERIORITY IN HUMANITARIAN ASSISTANCE/DISASTER RELIEF (HA/DR) OPERATIONS

Michael Sovereign, Professor

Command, Control, and Communications Academic Group

Sponsor: National Defense University

OBJECTIVE: Apply Joint Vision 2010 concepts to Military Operations Other Than War in the HA/DR arena. Explore new commercial C4ISR systems to HA/DR requirements for coordination of inter-agency, multi-national, NGO and PVO operations. Produce reports suitable for National Defense University ACTIS publications. Perform work at USPACOM headquarters.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Joint Vision 2010, Military Operations Other Than War, C4ISR

1997 THESIS ABSTRACTS CC

LOGISTICAL IMPLICATIONS OF OPERATIONAL MANEUVER FROM THE SEA

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The U.S. Marine Corps concept for the projection of naval power ashore is Operational Maneuver from the Sea (OMFTS). OMFTS calls for movement of Marines from ships at sea directly to objectives deep inland without requiring a pause to build-up combat power on the beach. Support for ground forces is expected to come from the sea and be delivered primarily by air. This demands that sea-based logistics assets remain sufficiently close to shore to allow air assets to conduct resupply operations directly to the battlefield. The implication of this is that Navy ships may sacrifice operational and perhaps tactical mobility while sustaining the Marine operation.

This thesis determines the distance from the coastline sea-based Combat Service Support (CSS) assets will be able to maintain and still support operations of a given magnitude, and how tactically constrained Navy ships will be in order to support this concept of expeditionary warfare. It focuses on the time-distance-weight/volume relationships involved, and takes into account characteristics of the resupply assets, such as aircraft availability, capacity, method of employment, and the effects of combat attrition. Three methods of employing a Marine Expeditionary Unit are studied, ranging from a traditional force mix to the use of small infestation teams. The analysis shows that the available CSS assets will not support a traditional ground force mix at the distances envisioned, but will support the use of small teams. To fully realize OMFTS and still allow ships to maintain the desired standoff from shore will require a shift to more lethal Marine forces with much smaller logistical demands. Until such a force is feasible, the Navy should plan on providing support to Marines from close to shore.

GLOBAL BROADCAST SERVICE FOR THE EXPEDITIONARY WARRIOR

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The battlefield has changed tremendously during the past decade due to major technical innovations. These changes have resulted in a requirement for high-speed, multimedia communications and greater bandwidth capabilities. Global Broadcast Service (GBS) technology is a military application of the commercial system Direct TV and is one way the military can address the need for greater bandwidth. Many of the two-way systems in the MILSATCOM architecture could be relieved of their burden by use of GBS. This thesis focuses on the Marine Corps and how its decision-makers can integrate GBS into the existing communications architecture. This is illustrated by using a Marine Expeditionary Unit as an example. This technology meets the warfighters need to have a high data rate, high volume information transfer available. Crucial to the successful integration of GBS into the communications architecture is ensuring that the MEU command ships, and other amphibious vessels in the Amphibious Ready Group, are equipped with the GBS receive suites during MEUs workup and deployment cycle. Finally, command and control issues are discussed and how GBS can expedite the decision making process.

1997 THESIS ABSTRACTS CC

JOINT DEPLOYABLE INTELLIGENCE SUPPORT SYSTEM (JDISS) COMMUNICATIONS AND IMAGERY APPLICATION GUIDE FOR NEW USERS

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LtCol Tim Phillips, U.S. Marine Corps Representative**

Dan C. Boger, Command, Control, and Communications Academic Group

The purpose of this thesis is to provide a Joint Deployable Intelligence Support System (JDISS) Communication and Imagery Application Guide for New Users. These two applications, together, are the core of the JDISS program. Both applications were examined to identify functions and processes that are difficult to understand as well as functions and processes that lack sufficient instructions for new users. The supporting JDISS Desktop and Utilities applications were added to provide the knowledge base required for the new user to use the Application Guide as a stand-alone document. Other JDISS applications, such as Office Tools, Email, Intelink, etc., are not included due, in part, to a common thread with other programs that the new user should already be familiar with, but mostly due to thefor interoperability (JBOC, 1996). Therefore, this detailed, step-by-step JDISS Communication and Imagery Application Guide for New Users was developed and designed to help future JDISS users world wide.

adequate help instructions readily available within the JDISS main desktop help function.

The JDISS program was developed to ensure that each of the U.S. Services and Agencies had an integrated intelligence system, and one that would provide a common data standard permitting interoperability both intra-service and inter-service. The Joint Staff, Director of Intelligence (J2), has highlighted JDISS in joint doctrine as the principal intelligence component

THE INTEGRATION OF SITUATIONAL AWARENESS BEACON WITH REPLY (SABER) WITH THE ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)

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Second Reader: LCDR Steve Iatrou, Information Warfare Academic Group

In 1992, the Joint Requirements Oversight Council validated a combat identification mission need statement. In support of the requirement for system interoperability, this thesis proposes a concept of operations for integrating two systems, Situational Awareness Beacon with Reply (SABER) and the Enhanced Position Location Reporting System (EPLRS).

SABER is a program initiated by Naval Space Command to provide real-time combat identification (CID) to the tactical user. It uses UHF satellite communications technology in conjunction with the Global Positioning System (GPS) to provide positioning information for up to 500 users.

EPLRS is a situational awareness program used extensively by the U.S. Army to support tactical battlefield operations. In addition to providing automatic friendly identification of EPLRS-equipped units, it has a communications capability that allows for the passage of intelligence and targeting data, messages, and status reports. However, EPLRS operates in a line-of-sight mode only and uses military grid reference coordinates vice GPS for positional information.

The integration of SABER and EPLRS has the potential to serve a major role in the armed services' common goal of reduced fratricide. This thesis gives a detailed description of both systems, examines their individual capabilities and limitations, discusses the ways in which the two systems complement each other, and provides a recommended integrated concept of operations.

1997 THESIS ABSTRACTS CC

WEAPONS OF MASS DESTRUCTION AND TERRORISM: PROLIFERATION BY NON-STATE ACTORS

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Executive Order No.12938 signed by President Clinton on November 14, 1994 declared a national emergency with respect to the unusual and extraordinary threat that proliferation of weapons of mass destruction (those weapons categorized as nuclear, chemical, or biological) poses to the national security, foreign policy, and economy of the United States.

In the wake of the Cold War, a new world disorder seems to be emerging wherein the legitimacy of many states is being challenged from within by increasing non-state calls for self-determination from the likes of religious cults, hate groups, isolationist movements, ethnic groups, and revivalist movements. These movements often prey on the insecurities of the population, offering to fill psychological, social, political, or religious security needs of those who would join them. Religious oriented groups appear to share a common ideology which rejects existing social, economic, and political structure demanding a drastic revision of the world—a world where they become the authoritarian, dominant influence. These are the Post-Modern Terrorists who possess a “ripeness” to threaten use of weapons of mass destruction.

This study presents an argument suggesting that terrorist groups operating under the veneer of religion are truly the most likely candidates to threaten use of weapons of mass destruction in a mass casualty causing terrorist act.

ANALYSIS OF TRANSFERRING U.S. NAVY PERRY CLASS FRIGATES TO TURKEY AND ISSUES RAISED DURING THE PROCESS

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This thesis analyzes the process used to transfer U.S. Navy Perry class frigates to Turkey and issues raised during this transfer process. Up to the final step, this transfer was representative of most U.S. military equipment transfers. The relations between allied countries depend heavily on the mutual support they provide to each other. Strong relations create strong mutual support, or vice versa. Although the FMS/FML process is a very effective process for ship transfers, political issues must never be underestimated. As the Cold War came to an end, the mutual threat had changed, affecting alliances and rephrasing the causes of their existence. The effect of this change has caused more domestic oriented policies to predominate within a country's political system.

Although this policy change didn't cause procedural changes in regulations and rules, the application of the decisions given and approved by the highest executive and legislative branch authorities are now more subjective and seem unpredictable. Long-term and continuous repetition of this behavior could cause negative impact on alliances.

1997 THESIS ABSTRACTS CC

COUNTER-ORGANIZATION TARGETING: A THEORETICAL FRAMEWORK FOR ANALYSIS

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and

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The purpose of this thesis is to present and substantiate a theory of counter-organization targeting. This thesis achieves this objective by creating and testing a framework for analysis which blends the principles of organization theory with classic counterinsurgency theory. The goal of this framework is to provide an analytical tool for operational-level targeting of adversary organizations during war, conflict, and stability and support operations.

This study analyzes the historical precedents of counter-organization targeting to demonstrate its viability as a necessary condition for success in counterinsurgency campaigns. Additionally, by applying the framework against an unresolved case, this study validates its applicability against a broader spectrum of the operational continuum. As a result, this thesis offers an innovative framework allowing for a logical and common sense approach to observing, assessing, targeting, and interdicting adversary organizations

COBRA BRASS FOR BATTLESPACE CHARACTERIZATION AND BATTLE DAMAGE ASSESSMENT (U)

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Battlespace characterization and battle damage assessment are important to the warfighter and must be a part of the strike planning. The Cobra Brass research and development sensor has the capability to provide information the warfighter can use to aid in his decision making. Navy TENCAP is using Cobra Brass in an operational mode to test the feasibility of operationally tasking this type of sensor. This thesis educates the warfighter on the Cobra Brass family of sensors, investigates the utility of Cobra Brass for battlespace characterization and battle damage assessment, and develops a concept of operations for the non-imaging infrared sensors presently deployed and for future such sensors.

DESIGN AND DEVELOPMENT OF THE SCENARIO FOR THE SECOND NPS A2C2 EXPERIMENT

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The Adaptive Architectures for Command and Control (A2C2) project is a research effort sponsored by the Office of Naval Research to explore adaptation in command and control structures. The project's second experiment builds on the first experiment. It studies the interaction between task structure and organization structure. This thesis builds on the work of previous theses by Michael Bergin and Scott Higgins. It describes a process for developing military operational scenarios within a task structure context. First, the author conducts a literature review, which defines the dimensions of task structure

1997 THESIS ABSTRACTS CC

applicable to this project, and describes how changes in one dimension might affect other dimensions. Then a method for developing scenarios in accordance with a predetermined structure and visualizing tasks is described, including a task structure diagram and a description of a task design process using the diagram and the dimensions previously delineated. The author then applies the task design process by developing two scenarios for the second NPS A2C2 experiment that differ across one dimension of task structure, coordination requirements. Finally, a description of the experiment is given, including discussion of operationalization of scenarios and organization structures, and lessons learned from the experiment with regard to scenario design.

COMMUNICATION MODULATION SIMULATORS: AN ASSESSMENT

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The military drawdown and budget cutbacks have created a greater emphasis on shorter, faster, and cheaper ways to do the mission. Modulation simulators have become a critical component in the evaluation and testing, and integration of new network, communications, and command and control technologies and applications.

This thesis evaluates five current commercial-off-the-shelf products: OPNET Modeler by MIL 3 Inc.; COMNET III designed by CACI Products Company; Extend by Imagine That Inc.; Workbench created by Scientific Engineering Software Inc.; and G2 from the Gensym Corporation. Each of the products is evaluated using twenty-five primary evaluation criteria. The evaluations include current costs, completeness, user interface, and post analysis support methods, and they describe the basic features and distinctive characteristics of each product.

The capabilities of the products are compared, providing the reader with the knowledge to make an informed product selection based on the user's needs. A matrix of the products and the evaluation criteria provides a quick overview of the analysis.

MODELING THE COMBAT POWER POTENTIAL OF MARINE CORPS CLOSE AIR SUPPORT

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This thesis proposes a numerical measure of the combat power potential of U.S. Marine Corps close air support (CAS) aircraft. The combat power potential of a weapon system is defined as the rate at which the system could deliver lethal fire to any point on the battlefield, accounting for particular and relevant battlefield and enemy characteristics. This measure is expressed in units of "kills-per-minute," where each point is hypothesized to have an infinite supply of instantaneously replaced targets.

The collection of these values (i.e., kills-per-minute for each battlefield point) is suitable for display as a "combat potential surface," overlaid on a battlefield map. In this thesis, points of higher potential are keyed to brighter colors (e.g., red, yellow, orange). The end result is a battlefield visualization tool to assist commanders and staffs in CAS planning.

1997 THESIS ABSTRACTS CC

AN EFFECTIVENESS STUDY FOR PRIORITIZATION ALGORITHMS IN A COMMUNICATIONS NODE MODEL FOR THE COPERNICUS TACTICAL DATA INFORMATION EXCHANGE SYSTEMS (TADIXS)

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The U.S. Navy has published its vision of the future in Command, Control, Communications, Computers and Intelligence (C4I): Copernicus. Copernicus takes advantage of new technology and attempts to answer the demand for larger amounts of more timely information. Despite the advances in technology, new transmission methods and increased bandwidth, the U.S. Navy still does not have all the communications throughput that it desires. The author examines message prioritization algorithms as a way of making more efficient use of scarce communications resources. Through a simple communication node model and two algorithms, it is statistically proven that prioritization algorithms can improve the efficiency of a communication system.

A COMPARATIVE STUDY OF CIVIL-MILITARY OPERATIONS PERSPECTIVES AS THEY APPLY TO PEACE SUPPORT OPERATIONS

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The post-Cold War world has been marked by the United Nation's approval and participation in the intervention into the affairs of sovereign states, often labeling them: Peace Support Operations (PSOs). While American interventions have been studied in terms of chain of command, firepower and rules of engagement problems, Civil-Military Operations (CMO) have not been analyzed in a comparative fashion. Given that future interventions are likely to occur, it is the responsibility of policy analysts and leaders to consider both the costs and benefits of democratic enlargement and the applicability of current CMO doctrine. To do this, tools are needed. This study provides three such tools.

First, case studies on the U.S. interventions in Somalia and Haiti provide a view of some of the questions and problems involved with intervening in the affairs of states for humanitarian or democratic enlargement issues. Second, the study pits contending theories against each other to see if one does a better job of explaining/predicting outcomes. Finally, the study provides recommendations on the implications of democratic enlargement, including the need for a Department of Defense, Department of State and civilian relief organization synchronization in regard to the military's requirement to: 1) intervene; 2) stabilize the situation; and 3) extract itself so that other agencies may consolidate democracy.

THE ARMY TACTICAL COMMAND AND CONTROL SYSTEM

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This thesis is a summary of the capabilities of the Army Tactical Command and Control System (ATCCS) and the guiding Command, Control, Communications, Computers and Intelligence (C4I) documents as they apply to the ATCCS. Its pur-

1997 THESIS ABSTRACTS CC

pose is to strengthen the knowledge base of Army officers entering the Joint C41 curriculum by providing a summary of Joint and Army C4 doctrine and guidance as it applies to ATCCS.

ATCCS is the Army's primary Command and Control (C2) system at echelons corps and below. ATCCS consists of five smaller systems, each a Battlefield Functional Area Control System (BFACS) controlling seven Battlefield Functional Areas (BFA). The five BFACS are the Maneuver Control System (MCS), the Advanced Field Artillery Tactical Data System (AFATDS), the Forward Area Air Defense Command, Control and Intelligence System (FAAD C21), the Combat Service Support Control System (CSSCS), and the All Source Analysis System (ASAS).

A clear strategy for the functional design of ATCCS is supported by three documents. Related to and supportive of each other, the three documents are Joint Pub 6-0, Doctrine for Command, Control, Communications and Computer Systems Support to Joint Operations; The Army Enterprise Strategy consisting of The Vision and The Implementation Plan; and Army Field Manual 100-5, Operations. This thesis draws threads of continuity from joint doctrine through Army guidance into implementation in ATCCS.

A STUDY OF NATIONAL RECONNAISSANCE OFFICE'S (NRO) FUTURE COMMUNICATIONS ARCHITECTURE (U)

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The National Reconnaissance Office (NRO) has identified much higher data rate requirements for future national systems. The goal of this thesis is to provide a possible alternate solution that would utilize crosslink technology developed for the Iridium Mobile Satellite System combined with existing and emerging laser communications technology. In addition to many other advantages over RF communications, laser communications can fulfill the extremely high data requirements of the future NRO systems. This technology could be a part of a new satellite constellation that can provide single and double global coverage in Stage I and Stage II, respectfully, of the satellite constellation design.

MULTIATTRIBUTE UTILITY ANALYSIS OF NON-SATELLITE COMMUNICATIONS (U)

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There is a growing awareness of U.S. overhead reconnaissance capabilities throughout the world today. In the last twenty years various entities have revealed portions of the U.S. overhead coverage and capability. Operation Desert Shield/Desert Storm served to underscore both the U.S. reliance on overhead collection and the robustness of this architecture. Additionally, there has been an effort to downgrade the classification of overhead intelligence products. While this provides additional intelligence to U.S. forces, allies, and coalition partners, it also provides a greater understanding of previously sensitive national programs to a wider audience.

Today there are many countries who have or are developing denial and deception programs. These countries may easily obtain information about U.S. overhead capabilities through a variety of means. Some countries may exploit overhead system vulnerabilities in order to enhance their own denial and deception programs.

With multiattribute utility analysis, a model was created with which one can evaluate overhead systems designed to thwart foreign exploitation. Through this model one way will be demonstrated in which U.S. overhead security may be maintained while still providing broad support to U.S. forces.

1997 THESIS ABSTRACTS CC

AN OPERATIONAL OVERVIEW OF NATIONAL SIGINT COLLECTION (U)

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National SIGINT collection remains both a national and fleet level priority. As such, a basic understanding of these collection systems is given emphasis at the Naval Postgraduate School for curriculums such as Space Systems Operations, Space Systems Engineering, and Information Warfare. Yet no one document or reference contains all relevant material for instruction of the subject, as taught at NPS. Also, most references do not present the material in a format readily assimilated by students with little or no experience in related fields.

This thesis is intended to produce a document which will provide an operational overview of all relevant national SIGINT collection systems. The primary product of this thesis is a hard copy paper which could be used both as a source for professors and as a reference for students studying national SIGINT collection. Operational usefulness, communications paths, and system differences are the primary topics of the paper. All topics will be researched with an operational, vice technical, consideration.

Additionally, a version of this operational overview has been placed on the INTELINK secure network. In the form of a web page (not unlike web pages found on the World Wide Web/Internet), the thesis then becomes a user-interactive learning tool. Users can visit the site, download relevant information, then follow hypertext links to related sites such as mission offices or reporting sites.

DIRECT BROADCAST TECHNOLOGY IN BOSNIA: ITS IMPACT ON THE DECISION-MAKING PROCESS AND JOINT ENDEAVOR OPERATIONS

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During Desert Storm a serious shortfall was identified in the communications architecture and its ability to effectively provide high-bandwidth information to meet the demands of the operation. In response to this shortfall, the Department of Defense (DoD) is pursuing the exploitation of commercial Direct Broadcast Satellite (DBS) technology and its ability to broadcast video and data at high rates to small, affordable, and portable terminals. The Global Broadcast Service (GBS) was initiated to ultimately provide this military direct broadcast capability.

A precursor to GBS, the Joint Broadcast Service (JBS), was begun as an Advanced Concept Technology Demonstration (ACTD). It is now leveraging DBS technology to support Operation Joint Endeavor. This thesis describes how the JBS works, what types of information are sent over the JBS, the complete process of information distribution, and the impact the JBS has had on Operation Joint Endeavor and the associated operational decision making process.

The JBS system has, at least in part, answered the joint warfighter's need for an improved high-bandwidth video and data distribution system. Although it does have force enhancement capabilities, the lack of familiarity, information management, and trust of the system have limited its effectiveness in Operation Joint Endeavor.

1997 THESIS ABSTRACTS CC

REQUIRED INFORMATION SYSTEMS KNOWLEDGE FOR NAVAL INTELLIGENCE OFFICERS

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Ralph Norman Channell, Department of National Security Affairs

To be effective in most current billets, Naval Intelligence Officers must have a baseline technical knowledge of computer hardware and software, data communications, and related-systems (known collectively as Information Technology). This thesis reviews survey data of common Intelligence Officer billets ashore and afloat as well as leadership statements and doctrine. Using these sources, knowledge requirements of existing and future Intelligence Officer assignments are identified in this study, and it is clear that these requirements are not currently being satisfied through standard intelligence training methods. An outline is provided of information technology fundamentals, military and commercial telecommunications, intelligence systems, applications, and connectivity to assist with formal or self-training programs.

Intelligence Officer training and education must include more information technology and intelligence architecture. Existing intelligence courses and other non-traditional programs should be better utilized by Naval Intelligence personnel. ONI or DIA should ensure that these programs are both current and readily available to Intelligence Officers throughout their entire careers.

ISSUES IN SPACE LAW AND POLICY

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Advisor: Dan C. Boger, Command, Control, and Communications Academic Group

Second Reader: Carl R. Jones, Department of Systems Management

This thesis provides a student studying space with background information and insight into selected issues that have shaped, or continue to shape, the world's approach to activities involving space. Further, the basic understanding gained through the study of these issues and their connection with international treaties and policies gives an appreciation for the regulatory side of space programs.

Some of the topics discussed are the delimitation and control of space, space debris, and the interpretation of the Anti-Ballistic Missile Treaty. Though they are often seen as issues in space law, it is shown that political considerations and decisions more often determine the outcome or path followed. Further, technical aspects and applications have seemingly usurped any laws which govern use, i.e., what can or cannot be done. Regardless, a commitment to the future use of space is as important as current operations.

This does not imply a need to quickly fill this legal void with well-meaning rules to provide structure. Rather, it is seen that certain laws do need to be created in order to ensure the continued access and use of space will not be interrupted.

REAL TIME INFORMATION IN THE COCKPIT MISSION UTILITY

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Second Reader: Dan Boger, Command, Control, and Communications Academic Group

Navy TACAIR mission effectiveness requires timely responses to emerging conditions in the operational environment. Mission effectiveness is improved by increasing pilot situational awareness with Real Time Information in the Cockpit (RTIC). Exploiting updated and new information from offboard sources provides accurate targeting, increases aircraft survivability, and expands mission flexibility. The evolution of RTIC, sensor to shooter, and offboard targeting concepts are summarized through a discussion of past RTIC exercises and Advanced Concept Technology Demonstrations. Existing

1997 THESIS ABSTRACTS CC

operations utilizing the Rapid Targeting System in EUCOM illustrates emerging concepts of operation. In order to assess RTIC mission utility, several TACAIR missions are analyzed for specific information requirements that RTIC can support. Measures of Effectiveness and Performance are identified and applied to a heuristic model to determine RTIC mission utility. An example is provided to illustrate the method's application. Finally, conclusions and observations are given regarding the RTIC utility methodology, on-going research initiatives, RTIC mission planning cycle impact, and areas for future studies.

OBJECT-ORIENTED PLAN REPRESENTATION FOR THE OMWG C2 OBJECT SCHEMA

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Tung Bui, Department of Systems Management

The purpose of this thesis is to examine current Command and Control planning methods and to aid in the furtherance of the Object Model Working Group's (OMWG) Core Plan Representation. Chapter I introduces the discipline of planning and its history. Chapter II discusses the theory and practice of modern Object-Oriented modeling. The structure and conventions of object programming are covered as well as a method for information system abstraction. Chapter III covers the background of current Command and Control systems and gives a report on the OMWG efforts in creation of an Object Schema for Command and control. Chapter IV presents the author's submission for an Object-Oriented representation of the COMSUBPAC OPLAN 5050 based on the Core Plan Representation (CPR).

MODELING THE EFFECTS OF TECHNOLOGICAL CHANGE ON COSTS FOR DIVERT/ATTITUDE CONTROL SYSTEMS

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The purpose of this thesis is to produce a usable Cost Estimating Relationship (CER) or Cost Model for the solid-propellant Divert/Attitude Control System (DACS) used in the Atmospheric Interceptor Technology (AIT) program kill vehicle. While developing this CER, several other areas are investigated, including technology measurement and cost estimation of systems that incorporate advanced technology. The data sample for this analysis was collected by Tecolote Research, Inc., and includes both antiballistic missile interceptor and antisatellite attitude control system data.

The analysis includes review and application of a method to measure the level of state-of-the-art of technology embodied in an attitude control system. This methodology also includes the ability to measure the advance, or extension, of that state-of-the-art proposed by a new development program.

Theoretical first unit cost estimates for the ALT DACS are developed by using existing CERs and by first measuring the level of technology to be embodied in the DACS and then building a cost model from these technology measures. The models developed by this procedure show a smaller 90% prediction interval than the 80% prediction intervals produced by the traditional CER approach.

Central to this analysis is the use of various statistical analysis techniques, primarily factor, and regression analysis. Recommendations for further research are also provided.

1997 THESIS ABSTRACTS CC

AN INVESTIGATION OF THE EXPECTED IMPACT OF THE SPACE BASED INFRARED SYSTEM (SBIRS) ON CUEING OF NAVY THEATER BALLISTIC MISSILE DEFENSE SHIPS(U)

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Master of Science in Information Technology Management-March 1997

Advisors: Dan C. Boger, Command, Control, and Communications Academic Group

Carl R. Jones, Department of Systems Management

This thesis studies tactical ballistic missile (TBM) position and velocity measurement accuracy available from the current Overhead Non-Imaging Infrared (ONIR) Defense Support Program (DSP) space-based sensors, and compares this measurement accuracy with the measurement accuracy improvements expected from the Space Based Infrared System (SBIRS). SBIRS is to replace the existing space-based sensors in the near future. The analysis is motivated by a requirement to improve the lethality of AEGIS class ships performing a defended area theater ballistic missile defense (TBMD) mission or a theater-wide TBMD mission.

TBM position and velocity measurements from space-based IR sensors can be handed off to the AEGIS TBMD ship as cueing information which enables earlier acquisition of the TBM by the shipboard AN/SPY-1B/D phased array radar. Earlier acquisition can enable earlier engagement and intercept of the missile at a greater distance from the ship. An analysis of the factors that introduce ONIR space sensor measurement error to the current satellites is performed and used as a baseline for comparison with the design approach and measurement improvements offered by the SBIRS spacecraft and ground processing stations. The result is investigated within the context of lethality improvements to the AEGIS TBMD ship against TBMs of various ranges.

A GOAL PROGRAMMING APPROACH FOR DETERMINING THE FORCE STRUCTURE OF NAVAL SURFACE GROUPS USING THE ANALYTIC HIERARCHY PROCESS

Erol Unal-Lieutenant Junior Grade, Turkish Navy

B.S., Turkish Naval Academy, 1991

Master of Science in Operations Research-March 1997

Advisors: Dan C. Boger, Command, Control, and Communications Academic Group

Gregory Hildebrandt, Department of Systems Management

A methodology for determining the force structure of naval surface groups is developed. A survey of naval surface officers is used to determine a surface ship's relative superiority over the others with respect to several factors (e.g., speed, warfare capabilities, surveillance capabilities, and fuel consumption). The Analytic Hierarchy Process (AHP) is employed to convert survey judgments into numerical preference weights. The AHP weights are then used as objective function coefficients in the mixed integer goal programming model formulations. The object of each model formulation is to select a preferred mix of ship types by minimizing the total deviation from one or more force level goals given certain system constraints such as budget, weapon requirements, and/or existing force levels.

A METHODOLOGY FOR AN IMAGERY VULNERABILITY ANALYSIS

Joseph R. Wessling-Lieutenant, United States Navy

B.S., Michigan State University, 1988

Master of Science in Space Systems Operations-September 1997

Advisor: Carl R. Jones, Department of Systems Management

Dan Boger, Command, Control, and Communications Academic Group

The proliferation of high resolution commercial remote sensing satellites over the next ten years will allow potential adversary countries to possess high quality imagery which can be used for intelligence purposes against U.S. forces. This thesis first provides a functional description of each segment of an imagery system, discusses relevant concepts of Command and

1997 THESIS ABSTRACTS CC

Control Warfare, and examines three existing vulnerability analysis taxonomies. The author then combines those elements of each taxonomy applicable to an imagery system with the principles of Command and Control Warfare and develops an imagery system vulnerability analysis methodology. This three-phased methodology describes how to determine the vulnerable nodes of an imagery system, provides a framework for developing ways to attack such a system, and presents a method to measure the effects of an attack on the system. Illustrations are provided to "walk " the reader through the methodology.

**INFORMATION WARFARE
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FACULTY LISTING IW

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DEPARTMENT SUMMARY IW

The Information Warfare Academic Group (IWAG) is an interdisciplinary group. Members hold faculty and staff appointments in departments throughout the Naval Postgraduate School and voluntarily hold seats on the IWAG. The IWAG is responsible for management, oversight, and implementation of the Information Warfare and International Electronic Warfare curricula.

Members of the IWAG make significant contributions in Information Warfare/Information Operations studies through their own research and student thesis work. The following pages highlight some of these areas of study. Research conducted by individuals in this unique grouping of academicians is generally associated with their parent department and therefore not listed here.

PROJECT SUMMARIES IW

STRATEGIC FRAMEWORK FOR INFORMATION WARFARE: TASK 4, THE DEVELOPMENT OF INFORMATION STRATEGY

John Arquilla, Associate Professor
Information Warfare Academic Group
Sponsor: RAND Corporation

OBJECTIVE: The "information strategy" project will develop a framework for analyzing the manner in which emerging information technologies may either serve as useful adjuncts to political, military and economic policies, or may form a distinct new "information strategic" dimension.

DoD KEY TECHNOLOGY AREA: Other (Information Warfare)

KEYWORDS: Information Warfare, Information Technologies

CHINESE BUDGETARY AND DEFENSE PLANNING PRIORITIES

John Arquilla, Associate Professor
Information Warfare Academic Group
Sponsor: Office of the Secretary of Defense

OBJECTIVE: Through processes of economic revitalization and institutional redesign, China has begun to actualize its enormous potential as an emerging great power. This will have major effects upon the world economy, but also on the nature of international security. A key aspect of China's rise as a military power will be the manner in which its economic growth as concomitant effects upon defense planning and budgetary processes. This project, therefore, will perform research in the area of determining China defense spending priorities for the near-and-long term future. The focus of this study will be on assessing the degree of preference being shown for spending that supports two areas of operations: force projection and information warfare. The research performed in this study will rely upon primary source materials provided primarily by means of field research activities.

DoD KEY TECHNOLOGY AREA: Other (Advance Telecommunication)

KEYWORDS: Information Warfare, Defense Budgetary Processes

INFORMATION OPERATIONS MODELING AND SIMULATION (IO M&S)

Vicente Garcia, National Security Agency Cryptologic Chair
CAPT James Powell
Information Warfare Academic Group
Sponsor: National Security Agency

OBJECTIVE: To develop a decision aid and methodology for modeling and simulating a decision-making influence network.

SUMMARY: NPS has applied SAIC's SIAM Influence Net Modeling Tool to Evident Surprise scenarios along with innovative IO options to address the requirement for Information Operations modeling and simulations. IO M&S has been a top three recommendation from ACOM's Evident Surprise IW/IO exercise for the past two years. An influence net model of a targeted country has been constructed with the assistance of SAIC and the ACOM J5. Developmental IO options integrated and the interaction and effects on leadership have been effectively demonstrated. The result is a first-look simulation of how leadership can be influenced by IO in real-world contingencies. Refinement of intelligence via Intelink and open sources from the Internet, along with strengthening causal relationships, is ongoing. NPS student and faculty developers have demonstrated the results of this analysis to CINCUSACOM, CINCUSNAVEUR, DIRNSA, GEN J.J. Sheehan, USMC

PROJECT SUMMARIES IW

(ret.), and other high-level decision-makers to show SIAM's value as an IO influence modeling and decision aid, and modeling and simulation research tool.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Information Operations)

KEYWORDS: Information Warfare, Information Operations, Modeling and Simulation, Influence Network

NPS NETWORK RESEARCH LAB
Vicente Garcia, National Security Agency Cryptologic Chair
CAPT James Powell
Information Warfare Academic Group
Sponsor: National Security Agency

OBJECTIVE: To understand and develop methods and tools to defend against external and internal computer network attacks.

SUMMARY: The NPS Network Research Lab supports Information Operations research in evaluating and demonstrating the vulnerability of network technologies from operating systems to network management tools to attack. This effort consists of information about the vulnerabilities of the entire scope of network technologies, research into, and demonstrations of the vulnerability of various technologies to attack methods and scenarios, and in depth analysis of network technologies focusing on end-to-end vulnerabilities.

DoD KEY TECHNOLOGY AREAS: Other (Information Warfare, Computer Network Attack/Defense)

KEYWORDS: Information Warfare, Information Operations, Computer Network Attack

THESES DIRECTED:

Collom, K.S. and Craig, J.E., "A High Power Microwave Application for Information Operations, Master's Thesis, Naval Postgraduate School," September 1997.

Buettner, R.R. and Harris, R.B., "A Comparative Analysis of Commercial-off-the-Shelf Software for use in Transmitting Sensitive but Unclassified Data," Master's Thesis, Naval Postgraduate School, September 1997.

Burns, E.J., "Performing Stand-Off Jamming using Global Hawk Unmanned Aerial Vehicle," Master's Thesis, Naval Postgraduate School, September 1997.

Frizzell, C.L., "Strategic Impact of Iranian Data Communications Upgrades," Master's Thesis, Naval Postgraduate School, September 1997.

Wilson, A.N., "Tactical Unmanned Aerial Vehicles used as Stand-In Jamming Platforms," Master's Thesis, Naval Postgraduate School, September 1997

PROJECT SUMMARIES IW

CURRICULUM DEVELOPMENT IN TACTICS, DOCTRINE, AND OPERATIONAL ANALYSIS

CAPT James Powell

Information Warfare Academic Group

Sponsor: Naval Engineering Logistics Office

OBJECTIVE: These funds will enhance the NPS students tactical development and education, specifically: support expanded use of Navy tactical information compendium at NPS. Support faculty in their research of the uses of microcomputers, simulations, and processes of Information Warfare (IW) and other simulations and associated data bases. Provide for the education of the faculty in areas of IW and joint tactics and doctrine. Provide support for NPS students and faculty doing thesis and research work in modeling, simulation, and wargaming (e.g., CVBG force projection, C4I, IW simulations, modeling, and intelligence support) at commands involved with analysis and doctrine development (e.g., NraD, TACTRAGRU, Naval War College, NAWC-WPNS, China Lake, NADC, CAN, NDU, Naval Doctrine Command, etc.). Provide for student, faculty and chair participation in such events as NWCS war games, ARPA projects, and tactical symposiums. Such participation is for the development of subjects suitable for student theses and faculty research in the technical, tactical, and doctrine area.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Modeling and Simulation

KEYWORDS: Information Warfare, Information Operations

WIDEBAND DIGITAL COMPRESSIVE RECEIVERS

D. Curtis Schleher

Information Warfare Academic Group

Sponsor: Secretary of the Air Force

OBJECTIVE: To investigate the application of digital pulse compression techniques to compressive receivers with an objective of increasing the overall bandwidth available from these receivers. Simulate an advanced digital wideband receiver with 8 GHz bandwidth using 1 GHz digital components and determine its bandwidth potential and sensitivities.

SUMMARY: Compressive receivers are advantageous in SIGINT applications requiring wide bandwidth in a dense emitter environment. Present implementations are limited in bandwidth by the analog nature of the design which requires a wideband dispersive delay line and also by the necessity of reading the output data at a digital rate which corresponds to the receiver's bandwidth.

This research describes a wideband digital compressive receiver which mitigates the limitations in the conventional analog design. A new stepped-frequency 8 GHz bandwidth digital design using 1 GHz sub-Nyquist sampling is described. The design was successfully demonstrated using MATLAB simulation. A bandwidth of 8 GHz was achieved using digital components which ran at a maximum 1 GHz clock rate. A 32 MHz resolution was measured as was the capability of separating 25 simultaneous signals occurring at the input of the receiver.

The bandwidth potential of this design was estimated as 16 GHz using 1 GHz digital components. Further research is required to realize the full potential of this design.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation

KEYWORDS: SIGINT, Compressive Receiver, Digital Pulse Compression

PROJECT SUMMARIES IW

INFORMATION WARFARE APPLIED TO THE JOINT C2W ATTACK MISSION

D. Curtis Schleher, Professor
Information Warfare Academic Group
Sponsor: Naval Postgraduate School

OBJECTIVE: To perform an independent technical study to identify a system which is capable of performing the joint C2W Attack Mission in the time period from the year 2000 to 2020.

SUMMARY: Under this research project, Unmanned Vehicles were identified as ideal platforms to perform the C2W attack missions. Two approaches were considered. In the first, the Global Hawk UAV was determined to have the necessary capacity and infrastructure to support the jamming mission. It was determined that this could be accomplished as an adjunct to its normal reconnaissance mission. Connectivity was improved over using conventional airborne assets due to its wideband data link and satellite connection.

The second approach used a small Predator UAV to accomplish "stand-in" jamming. An EW package using a small phased array antenna was investigated. This also was effective, but requires further study to determine tactics and deployment concepts.

THESIS DIRECTED:

Burns, E., "High Altitude Endurance Unmanned Aerial Vehicle used as a Stand-Off Jamming Platform," Master's Thesis, Naval Postgraduate School, June 1997.

Wilson, A., "Tactical Unmanned Aerial Vehicle used as Stand-In Jamming Platforms," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Command Control and Communications

KEYWORDS: Unmanned Aerial Vehicles, Stand-Off Jamming, Stand-In Jamming

INVESTIGATION OF HARD-KILL - SOFT-KILL INTERACTIONS

D. Curtis Schleher, Professor
Information Warfare Academic Group
Sponsor: Program Executive Office-Theatre Air Defense

OBJECTIVE: To investigate the interactions of soft-kill weapons (jammers, decoys, etc.) with hard-kill weapons (guns, interceptor missiles, etc.) in an air defense environment. Identify and catalog all potential interactions of each soft-kill system with each hard-kill system.

SUMMARY: Soft-kill and hard-kill mechanisms were identified and described. It was determined that interactions can occur in several ways, depending upon: 1) the role of the weapon (whether the weapon is the cause or the victim), 2) the nature of the interaction, direct or indirect, or 3) the number of ships and weapons involved in the engagement. An interaction polygon was developed which allows the various interactions to be visually displayed.

If hard-kill and soft-kill weapons are operated semi-independently, it was determined that both negative and positive interactions can occur, often unexpectedly and without being understood. Even beneficial effects of hard-kill/soft-kill integration are not necessarily advantageous if the commander lacks the knowledge of how to exploit them. A neural network approach is described which allows hard-kill/soft-kill mechanisms to be integrated into a single ship's defense system.

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Conventional Weapons

KEYWORDS: Electronic Combat, Countermeasures, Air Defense Weapons, Hard-kill, Soft-kill

PROJECT SUMMARIES IW

INDEPENDENT TECHNICAL ANALYSIS OF FLEET ASCM TRAINING SIMULATOR

D. Curtis Schleher, Professor

Information Warfare Academic Group

Sponsor: Naval Air Warfare Center-Indianapolis

OBJECTIVE: Anti-shipping missiles are a major threat to ships, particularly in the littoral environment; the Fleet Organic at Sea Training System needs to be upgraded to reflect threats and requirements through the year 2020. Through independent analysis, identify a functional simulator system which satisfies U. S. Navy and Amphibious Ready groups' anti-ship cruise missile training requirement in the years 2000 to 2020.

SUMMARY: Under this research project, an independent technical analysis of an improved ALQ-170 simulator was conducted. The analysis resulted in the identification of a preferred system design capable of providing anti-ship cruise missile (ASCM) defense training through the years 2000 to 2020.

The research used a system engineering approach to identify a preferred system design. A balanced set of requirements were determined on the basis of the Operational Requirement Document (ORD) and fleet messages. Measures of Effectiveness (MOE) and Measures of Performance (MOP) were determined from the requirements. A top level functional decomposition was performed to identify critical elements of the system. Four design alternatives were synthesized which range from a modification of the current design to a fully coherent, multi-polarization, broad band simulator with "dual-threat" capability.

The various design alternatives were examined through a series of trade-off analysis studies. Preferred solutions for critical components of the transmitter, antenna, receiver and system characteristics were developed. A decision matrix method was used in the trade-off studies where weights were related to a prioritized set of system performance measures. A preferred solution was identified which used helix TWTs supported by a wide band quadridge multi-polarization horn fed reflector antenna.

THESIS DIRECTED:

Goldsmith, G. L., "System Analysis of New ASCM Simulator," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Anti-Ship Cruise Missile, Simulator, System Engineering

PUBLICATIONS/PRESENTATIONS IW

TECHNICAL REPORTS

Schleher, D.C., "Independent Technical Analysis of Fleet ASCM Training Simulator," Naval Postgraduate School Technical Report, NPS-EC-97-021, January 1997.

Schleher, D.C., "Wideband Digital Compressive Receivers," Naval Postgraduate School Technical Report, NPS-IW-97-001, December 1997.

Schleher, D.C., "Investigation of Hard-kill - Soft-kill Interactions," Naval Postgraduate School Technical Report, NPS-IW-97-002, November 1997.

BOOK

Arquilla, John and Ronfeldt, David (eds.), *In Athena's Camp: Preparing for Conflict in the Information Age* (Rand, 1997).

1997 THESIS ABSTRACTS IW

A STUDY OF THE EFFECTS OF COUNTERMEASURE DISPENSER LOCATION ON INFRARED DECOY EFFECTIVENESS (U)

Scott R. Blake-Lieutenant, United States Navy

B.S., Norwich University, 1988

Master of Science in Aeronautical Engineering-March 1997

Advisors: F. Levien, Information Warfare Academic Group

Robert E. Ball, Department of Aeronautics and Astronautics

The latest generation of infrared guided missiles employs a wide variety of techniques designed to discriminate between the target aircraft and flares. As a result, every aspect of a flare design and employment has become increasingly important. In response to the threat, countermeasure designers are having to rethink countermeasure design and employment.

This study focuses on one aspect of the problem facing countermeasures designers, that of dispenser location. To that end the effectiveness of the current SH-60B Seahawk dispenser locations will be compared to those of the planned SH-60R. Each configuration will employ pyrotechnic and pyrophoric flares against a counter-countermeasures capable threat in hovering, non-maneuvering and maneuvering scenarios.

UNCLASSIFIED FEASIBILITY OF REPLACING OR SUPPLEMENTING THE EA-6B SUPPORT JAMMING SYSTEM USING UAV BASED JAMMER(U)

Edwin J. Burns-Lieutenant, United States Navy

B.S., Iowa State University, 1989

Master of Science in Systems Engineering-September 1997

Advisor: Curtis D. Schleher, Information Warfare Academic Group

Second Reader: Donald v.Z. Wadsworth, Department of Electrical and Computer Engineering

(U) There are increasing demands by theater CINCS for EA-6B Electronic Attack aircraft to provide Stand-Off-Jamming support during peace operations, as well as to protect aircraft which have missions near and within hostile countries. To reduce some of the demands for the EA-6B, large-payload Unmanned Aerial Vehicles (UAVs) containing stand-off Electronic Attack packages are now feasible. This study analyzes the feasibility of replacing or supplementing the EA-6B support jamming system using a UAV based jammer. The Global Hawk UAV with the ALQ-99 Electronic Attack system are the base systems for this study. This added support along with Global Hawks increased connectivity, higher survivability, and long on station time would give the EA-6B added flexibility in its employment against advanced radar and SAM systems. Global Hawk would still perform its primary mission of collecting airborne imagery, when not required to support the Suppression of Enemy Air Defenses. In order to determine the appropriate Concept of Operations for Global Hawk as a Stand-Off-Jammer, this study includes a threat analysis, and a determination of required airframe and electrical modifications.

THE INTEGRATION OF SITUATIONAL AWARENESS BEACON WITH REPLY (SABER) WITH THE ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)

Valerie Rosengarn Byrd-Lieutenant Commander, United States Navy

B.S., Pennsylvania State University, 1984

Master of Science in Systems Technology-December 1996

Advisor: Dan C. Boger, Command, Control, and Communications Academic Group

Second Reader: LCDR Steve Iatrou, Information Warfare Academic Group

In 1992, the Joint Requirements Oversight Council validated a combat identification mission need statement. In support of the requirement for system interoperability, this thesis proposes a concept of operations for integrating two systems, Situational Awareness Beacon with Reply (SABER) and the Enhanced Position Location Reporting System (EPLRS).

SABER is a program initiated by Naval Space Command to provide real-time combat identification (CID) to the tactical user. It uses UHF satellite communications technology in conjunction with the Global Positioning System (GPS) to provide positioning information for up to 500 users.

1997 THESIS ABSTRACTS IW

EPLRS is a situational awareness program used extensively by the U.S. Army to support tactical battlefield operations. In addition to providing automatic friendly identification of EPLRS-equipped units, it has a communications capability that allows for the passage of intelligence and targeting data, messages, and status reports. However, EPLRS operates in a line-of-sight mode only and uses military grid reference coordinates vice GPS for positional information.

The integration of SABER and EPLRS has the potential to serve a major role in the armed services' common goal of reduced fratricide. This thesis gives a detailed description of both systems, examines their individual capabilities and limitations, discusses the ways in which the two systems complement each other, and provides a recommended integrated concept of operations.

WEAPONS OF MASS DESTRUCTION AND TERRORISM: PROLIFERATION BY NON-STATE ACTORS

**James Kendall Campbell-Commander, United States Navy
B.A., San Francisco State University, 1978**

Master of Arts in National Security Affairs-December 1996

Advisors: John Arquilla, Information Warfare Academic Group

Gordon McCormick, Command, Control, and Communications Academic Group

Executive Order No.12938 signed by President Clinton on November 14, 1994 declared a national emergency with respect to the unusual and extraordinary threat that proliferation of weapons of mass destruction (those weapons categorized as nuclear, chemical, or biological) poses to the national security, foreign policy, and economy of the United States.

In the wake of the Cold War, a new world disorder seems to be emerging wherein the legitimacy of many states is being challenged from within by increasing non-state calls for self-determination from the likes of religious cults, hate groups, isolationist movements, ethnic groups, and revivalist movements. These movements often prey on the insecurities of the population, offering to fill psychological, social, political, or religious security needs of those who would join them. Religious oriented groups appear to share a common ideology which rejects existing social, economic, and political structure demanding a drastic revision of the world—a world where they become the authoritarian, dominant influence. These are the Post-Modern Terrorists who possess a “ripeness” to threaten use of weapons of mass destruction.

This study presents an argument suggesting that terrorist groups operating under the veneer of religion are truly the most likely candidates to threaten use of weapons of mass destruction in a mass casualty causing terrorist act.

A HIGH POWER MICROWAVE APPLICATION FOR INFORMATION OPERATIONS (U)

**Kurt Steven Collom-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1985**

Aerospace Engineering, May 1985

Master of Science in Systems Engineering-September 1997

and

**James Edward Craig-Captain, United States Army
B.S., Texas A&M University, 1986**

Physics, December 1986

Master of Science in Systems Engineering-September 1997

Advisors: Captain J.R. Powell, Information Warfare Academic Group

M.A. Morgan, Department of Electrical and Computer Engineering

(U) This thesis documents the requirement, concept, and validation process for the feasibility demonstration of a high power microwave application for Information Operations. Information Warfare (IW) and Information Operations (IO) are about providing the commander or decision-maker with options. Information Attack provides new courses-of-action for the commander when pursuing his mission objectives and gives him unique capabilities to attack the adversary in previously unimaginable ways. In order to procure any new weapons system, there must be a valid requirement for the system. In some cases, if the technology already exists, or if the system under consideration is an extension of an existing requirement, the

1997 THESIS ABSTRACTS IW

new system concept may be validated by a feasibility demonstration. Supporting documents to this thesis provide summaries of testing conducted to demonstrate and quantify the potential effectiveness of the application.

A ROBUST METHODOLOGY TO EVALUATE AIRCRAFT SURVIVABILITY ENHANCEMENT DUE TO COMBINED SIGNATURE REDUCTION AND ONBOARD ELECTRONIC ATTACK

Brian M. Flachsbart-Lieutenant Commander, United States Navy

B.S., United States Naval Academy, 1986

Master of Science in Aeronautical Engineering-June 1997

Advisor: Robert E. Ball, Department of Aeronautics and Astronautics

Second Reader: CAPT James R. Powell, Information Warfare Academic Group

This thesis examines the effect of combining radar signature reduction and onboard electronic attack (EA) capability on the survivability enhancement of a generic joint strike fighter (JSF). The missions of a generic JSF are examined, and a tactical scenario for an air-to-air mission and a strike mission are presented. The principles of signature reduction and EA using onboard Electronic Countermeasures (ECM) are reviewed. The effect of signature level and of jammer effective radiated power (JERP) on the ability of a radar to detect the JSF are determined individually. Finally, an approach for combining the two survivability enhancement features is described, in the context of the two tactical JSF scenarios, and an EXCEL spreadsheet program entitled RCS-JERP is developed using unclassified radar and EA equipment data. Although all of the material in this thesis and in RCS-JERP are unclassified, the principles, methodology, and spreadsheet can be applied to specific (and classified) scenarios by utilizing the specific radar data, applicable mission threat analyses, and the effectiveness of the specific EA techniques employed.

STRATEGIC IMPACT OF IRANIAN DATA COMMUNICATIONS UPGRADES (U)

Connie L. Frizzell-Lieutenant Commander, United States Navy

B.S., United States Naval Academy, 1986

Master of Science in Systems Engineering-September 1997

Advisors: Captain James R. Powell, Information Warfare Academic Group

Vicente Garcia, National Security Agency Cryptologic Chair

Second Readers: Mark Cleveland, National Security Agency

Fred Levien, Information Warfare Academic Group

Information Warfare goals include assessing an objective from a broad perspective, including the entire system of which the target in question is impacted by. This paper performs a case study against new, modern telecommunications systems and their impact on national strategies. Specific areas which effect the decisions of the top government officials are studied and reviewed. The impact of culture and how it prejudices a decision-maker is integrated with geographic and climate concerns. Other concerns, such as demographics and the impact this has on new installations is then added to the mix. These issues are then represented as a background to the more technical aspects of the telecommunications upgrades being experienced. Specifically, the digitization of all areas of the radio frequency spectrum and the innovation in switching technologies are included as part of this technological explosion and advance. Finally, the impacts the decisions (regarding the technological upgrades) have on national strategies, national policies, and how they impact the United States are addressed.

1997 THESIS ABSTRACTS IW

A SYSTEM ANALYSIS OF A NEW ASCM SIMULATOR

Galen Lee Goldsmith-Lieutenant, United States Navy

B.S., University of Wisconsin-Madison, 1988

Master of Science in Aeronautical Engineering-March 1997

Advisors: D. Curtis Schleher, Information Warfare Academic Group

Russell W. Duren, Department of Aeronautics and Astronautics

This research applied a Systems engineering approach to identify the technical characteristics for an improved ALQ-170(V) Anti-Ship Cruise Missile (ASCM) simulator. This simulator pod attaches to a F/A-18C Hornet to provide ASCM defense training. The new simulator provides a fully coherent, multi-polarization, broad band simulator that emulates all current and postulated ASCM threats through the year 2020.

A set of requirements were developed from the Operational Requirements Document (ORD) for the ALQ-170 Performance Enhancement Program (PEP) and fleet messages. Five design alternatives were examined through a number of trade-off studies in order to identify a preferred configuration. Multiple Attribute Utility Theory (MAUT) was used to score the five alternatives to determine the best possible replacement for the ALQ-170. The preferred configuration provides true "dial-a-threat" capability whereby any one of over 125 known ASCM threats are simulated upon operator command.

THE RULES OF ENGAGEMENT IN THE CONDUCT OF SPECIAL OPERATIONS

Michael S. Reilly-Lieutenant Commander, United States Navy

B.S., United States Naval Academy, 1986

Master of Arts in National Security Affairs-December 1996

Advisor: John Arquilla, Information Warfare Academic Group

Second Reader: Wayne P. Hughes, Jr., Department of Operations Research

This thesis examines the effect that ROE have on the conduct of special operations in order to contribute to an increased understanding of the proper employment of elite forces. It argues that "inappropriate" ROE can result from: 1) an imbalance in the natural tension between the requirements of statecraft and military efficiency present in all military operations and 2) organizational friction resulting from inaccurate translation of broad political objectives, through various levels in the chain of command, into an inappropriate tactical ROE for a specific unit. Additionally, it argues that the nature of special operations, and the principles vital to their proper employment, cause them to be most sensitive to these sources of inappropriate ROE in either crisis or conflict. This thesis concludes that ROE can be used to achieve indirect political control over special operations, but achieving this control is more difficult and more hazardous with special operations than with conventional forces.

A STUDY ON THE INFRARED SUSCEPTIBILITY OF THE SH-60B SEAHAWK TO THE SA-16 GIMLET IR SAM (U)

Edward J. Roth-Lieutenant, United States Navy

B.S., United States Naval Academy, 1989

Master of Science in Aeronautical Engineering-March 1997

Advisors: F. Levien, Information Warfare Academic Group

Robert E. Ball, Department of Aeronautics and Astronautics

The survivability of a helicopter in a hostile man-made environment is a function of the aircraft's vulnerability and susceptibility. Because vulnerability is determined in the aircraft's design, susceptibility is the primary concern of the aircrew and mission planners.

The Navy's SH-60B Seahawk was initially designed for the primary mission of Undersea Warfare (USW) in the benign open ocean environment. It has since evolved into a multi-mission platform with the added roles of Antisurface Warfare (ASUW) and ASUW attack. Furthermore, the helicopter must now confront the potential threats associated with the littorals, those coastal regions characterized by high sea and air traffic.

1997 THESIS ABSTRACTS IW

This thesis will investigate the susceptibility of the SH-60B Seahawk to the Russian SA-16 infrared missile, a man-portable air-defense system (MANPAD). The digital computer program MOSAIC (Modeling System for Advanced Investigation of Countermeasures) will be used to evaluate the SH-60B's current infrared countermeasure systems.

**SPACE SYSTEMS
ACADEMIC GROUP**

**Rudolf Panholzer
Chair**

FACULTY LISTING

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GROUP SUMMARY SP

The Space Systems Academic Group (SSAG) is an interdisciplinary association providing direction and guidance for the Space Systems Engineering and Space Systems Operations curricula. The SSAG relies on faculty and facilities support from the Departments of Aeronautics and Astronautics, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Operations Research, Physics, and Systems Management. The SSAG also benefits from the support of four Academic Space Chairs: Navy TENCAP Space Chair, Naval Space Technology Program Chair, Navy Space Systems Academic Chair, and Michael J. Smith Space Systems Chair.

The mission of the SSAG is threefold. The SSAG designs the curricula to provide a firm foundation in the broad array of disciplines which comprise the focus for Space Systems Engineering and Space Systems Operations. The SSAG also directs space research at NPS, thereby promoting practical learning opportunities through both theoretical and hardware-based thesis research. The third role of the SSAG is to ensure that officer students in the Space Systems Curricula receive practical experience through experience tours. A six-week experience tour is taken by each officer student hosted by any of a number of facilities from industry, Federal Government, or other universities.

Marrying the academic goals of the SSAG with the practical application of space technology for defense needs, the ongoing small satellite project provides an environment ideal for students to gain experience in design, development, testing, system integration, and operations of spacecraft and payloads. Officer students are exposed to space related research topics as well as formal classroom instruction. Many officer students have chosen research topics directly related to the small satellite design studies program.

In the 1997 academic year, officer students in the Space Systems Curricula and participating faculty from several departments were involved with the Petite Amateur Navy Satellite (PANSAT) project.

1997 SSAG membership includes:

Professor Rudolf Panholzer (Space Systems), Chair
Professor Brij Agrawal (Aeronautics and Astronautics)
Alan Ross (Space Systems), Navy TENCAP Space Chair
Craig Baldwin (Space Systems), Navy Space Systems Academic Chair
Tom Betterton (Space Systems), Naval Space Technology Program Chair
Professor Oscar Biblarz (Aeronautics and Astronautics)
Professor Dan Boger (Systems Management)
Associate Professor David Cleary (Physics)
Professor Donald Danielson (Mathematics)
Professor James Eagle (Undersea Warfare)
Lieutenant Commander D. Farley, USN
Assistant Professor Douglas Fouts (Electrical and Computer Engineering)
Vicente Garcia (Electrical and Computer Engineering), National Security Agency Cryptologic Chair
Professor Ashok Gopinath (Mechanical Engineering)
Lois Scaglione (Space Systems), NASA Michael J. Smith Space Systems Chair
Professor Carl R. Jones (Systems Management)
Visiting Assistant Professor Barry Leonard (Aeronautics and Astronautics)
Professor Herschel H. Loomis (Electrical and Computer Engineering)
Associate Professor Sherif Michael (Electrical and Computer Engineering)
Professor Conrad Newberry (Aeronautics and Astronautics)
Associate Professor Chris Olsen (Physics)
Assistant Professor Michael Ross (Aeronautics and Astronautics)
Instructor Randy Wight (Electrical and Computer Engineering)
Commander Michael McMaster, USN, Curricula Officer

GROUP SUMMARY SP

SMALL SATELLITE DESIGN STUDIES PROGRAM

Directed by Professor Rudolf Panholzer, the Small Satellite Design Studies Program is part of the Spacecraft Technology research effort incorporating proven and leading-edge technology in a space system development project. The Small Satellite Design Studies project continues in the development of the Petite Amateur Navy Satellite (PANSAT) space system. PANSAT is a small satellite being developed at NPS by officer students, faculty, and staff, for launch into a low-Earth orbit as a secondary payload via the Shuttle Hitchhiker program. Launch and integration is provided by the Department of Defense Space Test Program (STP).

PANSAT will provide digital communications using direct sequence spread spectrum using the amateur radio ultra-high frequency (UHF) band. Communications will be centered at 436.5 MHz with approximately 2.5 MHz of bandwidth. Transmission data rate will be 9.842 kbps using a 7-bit shift register with taps at 7 and 1 for the generation of the pseudonoise (PN) code.

PANSAT will perform store-and-forward message relay, meaning messages received by the spacecraft will be stored on-board until they are commanded to be down-linked to the ground station. This is done autonomously by the spacecraft through its on-board processor and memory. Thorough testing of the electronics and software which controls the on-board processing is currently in progress to ensure a robust system. During the 1997 fiscal year, progress was made in hardware development, software development, mission operations, as well as issues related to flight opportunities and Shuttle integration.

Spacecraft Development

The PANSAT spacecraft consists of the digital control subsystem (DCS), electrical power subsystem (EPS), communications payload (COMM), and the mechanical structure. Progress was made in FY97 in all areas of hardware development. All subsystems have been prototyped and are currently undergoing testing for functionality and software control. Prototype electronics also have been integrated on the benchtop to investigate functionality and control algorithms by software. Specifically, the radio frequency transmit and receive modules were fabricated and undergoing testing, a spread spectrum modem was fabricated and being controlled through a development system, and a processor board is undergoing further functionality testing for control of the other subsystems such as the memory modules. Flight hardware was developed for the memory modules which hold 4.5 megabytes each of storage capacity.

In addition to the progress in electronics development, the spacecraft structure and mechanical systems were completed with the exception of a few mounting hardware items to be finished. Subsystem environmental testing is beginning and a thermal analysis of the PANSAT has started by officer students, LCDR Paul Overstreet and LT Travis Smith, respectively. Software issues for the ground user interface are continuing with work by LT Ken Hunter.

Programmatic Developments

Other progress included an increase in dialogue between NPS, STP, and NASA during the FY97 period for an eventual Shuttle flight. PANSAT was moved to be included in the third International Extreme-ultraviolet Hitchhiker (IEH-3) payload targeted for the STS-95 Shuttle mission. NASA safety issues for PANSAT as a Shuttle payload continued to be worked out between NPS and NASA Safety personnel. A technical interchange meeting was held at NASA Goddard Space Flight Center for all payload experimenters who are part of the IEH-3 on June 20.

PROJECT SUMMARIES SP

SPACECRAFT SYSTEMS

B.N. Agrawal, Professor

Department of Aeronautics and Astronautics

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The goal of this project was to develop four spacecraft laboratories at NPS: FLTSATCOM Laboratory, Spacecraft Test Laboratory, Spacecraft Dynamics and Control Laboratory, and Spacecraft Design Laboratory. It is a continuing project.

SUMMARY: During the reporting period, significant progress has been made in several areas. In the Spacecraft Attitude Dynamics and Control Laboratory, implementation of the dSPACE Real Time Control System on the NPS Flexible Spacecraft Simulator (FSS) has been successfully completed and the FSS has been made operational. The Computational Spacecraft Design Laboratory was upgraded both in hardware and software, including Pro/ENGINEER, Pro/Mechanica, MSC/Nastran and COSMOS/M Engineer. Three spacecraft design projects were completed. The mission for the first project was to investigate three asteroids in the main belts. The project was done under AIAA/Lockheed Martin Graduate Competition and won second position. The second project was on a medium earth orbit UHF satellite constellation. This project was sponsored by the Naval Space Command and was in direct support of DoD's effort to analyze alternative solutions for the replacement of the UHF Follow-on (UFO) constellation. The third project was EHF satellite with a classified payload.

PUBLICATIONS:

Agrawal, B., Song, G., and Buck, N., "Slew Maneuvers of Flexible Spacecraft Using Input Shaping and Pulse-Width Pulse-Frequency Modulated Thrusters," IAF-97-A.2.09, *Proceedings of the 48th International Astronautical Congress*, Turin, Italy, 6-10 October 1997.

Agrawal, B., McClelland, R., and Song, G., "Attitude Control of Flexible Spacecraft Using Pulse-Width Frequency Modulated Thrusters," accepted for publication in *Space Technology Journal*.

Song, G., Buck, N., and Agrawal, B., "Spacecraft Vibration Using Pulse-Width Pulse Frequency Modulated Input Shaper," *Proceedings of AIAA Guidance, Navigation, and Control Conference*, New Orleans, LA, 11-13 August 1997.

Yale, G. and Agrawal, B., "A Lyapunov Controller for Cooperative Space Manipulators," accepted for publication in *AIAA Journal of Guidance, Control, and Dynamics*.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Design, Spacecraft Attitude Control, Space Manipulator

A NOVEL TECHNIQUE FOR SEARCH AND GEOLOCATION OF SIGNALS FROM LOW-EARTH ORBIT

David D. Cleary, Associate Professor

Department of Physics

Sponsor: United States Navy

OBJECTIVE: The objective is to investigate new techniques for search and geolocation using receiver systems that have both wide field-of-view and high gain.

SUMMARY: An imaging system was designed that can operate at radar frequencies and has in principle both wide field-of-view and high gain. This system makes use of a technique known as multiplexed imaging. The concept of operations (CONOPS) under which this device would be used was developed. Currently, the expected performance of this device is being analyzed including the estimated sources of system noise.

PROJECT SUMMARIES SP

OTHER:

A Multiplexed Imaging System for Microwave Frequencies, Navy Case No. 78779 (patent filed).

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Hyperspectral Imaging

THEATER BALLISTIC MISSILE DEFENSE-MULTI-SENSOR FUSION, TRACKING, AND TARGETING TECHNIQUES

Robert G. Hutchins, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Navy Tactical Exploitation of National Capabilities (TENCAP) Office

OBJECTIVE: The ultimate goal is to assess the feasibility of algorithms employing both strategic and theater sensors to detect, track, and engage theater ballistic missiles during boost and/or early ballistic missile flight, destroying the missile over the territory of the aggressor.

SUMMARY: The research this past year has focused on initialization and tracking of ballistic missiles during boost phase and through the transition between boost and ballistic flight. Various tracking algorithms have been studied. The effects of initialization on tracker performance to assess the feasibility of performing a hand-off between satellite and earth-based sensors are currently being examined.

PUBLICATION:

Hutchins, R.G. and San Jose, A.P., IMM Tracking of a Theater Ballistic Missile during Boost Phase," Oliver Drumond, (ed.), *Proceedings of SPIE Signal and Data Processing of Small Targets*, Vol. 3373, pp. 528-537, 1998.

CONFERENCE PRESENTATION:

Hutchins, R.G. and San Jose, A.P., "IMM Tracking of a Theater Ballistic Missile during Boost Phase," SPIE Signal and Data Processing of Small Targets, Orlando, FL, April 1998.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Theater Ballistic Missiles, Sensors, Extended Kalman Filters, Data Association, Target Tracking

PROJECT GUSTY ORIOLE, COMPUTER ALGORITHMS AND ARCHITECTURES FOR SPACE APPLICATIONS

Herschel H. Loomis, Professor

Department of Electrical and Computer Engineering

Sponsor: Secretary of the Air Force

OBJECTIVE: This project is concerned with the application of computer algorithms to specific military space projects, the development of specialized computer architectures for military space applications and the support of the space operations curriculum.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Military Space, Computer Architectures

PROJECT SUMMARIES SP

RADIATION HARDENING OF SPACE-BASED ELECTRONIC DEVICES AND SOLAR CELLS

Sherif Michael, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Naval Research Laboratory

OBJECTIVE: To study the space radiation effects on state-of-the-art solar cells including GaAs and InP cells. To investigate annealing methods developed in previous NPS research on the recovery of radiation degraded performance of advanced space cells and develop radiation hardened Analog VLSI circuits for space applications.

SUMMARY: Continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include optimizing current annealing methods previously developed for GaAs cells. The tasks also include investigating of the new laser annealing technique on GaAs and InP solar cells. Irradiating solar cells using NPS Linear Accelerator, and measuring their characteristics using the newly developed Solar Simulator Facilities. Other tasks are to investigate radiation effects on different electronic devices. Radiation testing of Analog VLSI chips previously designed and fabricated, using the NPS Linear Accelerator. Major Research: 1) annealing of radiation-damaged solar cells, 2) investigating of Laser Annealing techniques for radiation-damaged solar cells, and 3) radiation tolerant ASIC and analog IC design, implementation and testing.

PUBLICATIONS:

Michael, S., Shehata, K., and Fouts, D., "Analog/Digital Gallium Arsenide Circuits and Systems Design," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA, August 1997.

Michael, S., Shehata, K., and Fouts, D., "Dynamic Logic Families for Complementary Gallium Arsenide (CgaAs) Fabrication Processes," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA August 1997.

Michael, S. and Oldland, H., "A GaAs Mixed Mode Switched Capacitor VLSI," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA, August 1997.

CONFERENCE PRESENTATION:

Michael, S., "A GaAs Mixed Mode Switched Capacitor VLSI," 40th Midwest Symposium on Circuits and Systems, Sacramento, CA, August 1997.

THESES DIRECTED:

Oldland, H., "The VLSI Implementation of a GaAs GIC Switched Capacitor Filter," Master's Thesis, Naval Postgraduate School, June 1997.

Reason, J., "A Comparative Study of Nuclear Technology and Direct Energy Conversion Methods for Space Power Systems," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Space Radiation Effects, Satellites, Annealing Radiation Hardened

PROJECT SUMMARIES SP

SPACE SYSTEMS STUDENTS THESIS RESEARCH PROJECTS

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Naval Research Lab

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) students thesis research projects, directed studies, and space engineering experience tours.

THESES DIRECTED:

Elder, J.T., "Optimal Impulse Conditions for Deflecting Earth Crossing Asteroids," Master's Thesis, Naval Postgraduate School, June 1997.

Horning, J.A., "System Controller Hardware and Embedded Software for the Petite Amateur Navy Satellite (PANSAT)," Master's Thesis, Naval Postgraduate School, September 1997.

Lahti, C.A., "The Design of the Radio Frequency (RF) Subsystem Printed Circuit Boards for the Petite Amateur Navy Satellite (PANSAT)," Master's Thesis, Naval Postgraduate School, June 1997.

Lambley, A.S., "Evaluation of Layout Techniques for Radiation Tolerant Bulk CMOS Integrated Circuits," Master's Thesis, Naval Postgraduate School, September 1997.

Reason, J.P., "A Comparative Study of Nuclear Technology and Direct Energy Conversion Methods for Space Power Systems," Master's Thesis, Naval Postgraduate School, June 1997.

Smilowitz, G.J., "Final Design, Integration, and Validation of the PANSAT Antenna System," Master's Thesis, Naval Postgraduate School, March 1997.

Stelianos. H., "The Use of Commercial Low Earth Orbit Satellite Systems to Support DoD Communications," Master's Thesis, Naval Postgraduate School, December 1996.

Triska, N.E., "The Astrodynamics Problems of Digital TDMA Signal Detection," Master's Thesis, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicle, Sensors, Command, Control, and Communications, Electronics, Other (Space)

KEYWORDS: Satellite Digital Communications, Direct Sequence Spread Modulation, Over-The-Horizon Communications, Amateur Satellite, Thin-Film Ferroelectric Material

SPACE OPERATIONS EXPERIENCE TOURS

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Naval Space Command

OBJECTIVE: The objective is to provide direct interaction between the signatories to further promote and guide a focused, well-defined, and well-planned support system essential to ensure a successful experience tour program. This program will provide valuable opportunities for practical professional development of students at NPS and will be an important investment in the Department of the Navy's strategy for Space Systems.

PROJECT SUMMARIES SP

THESIS DIRECTED:

Bradley, D.R., "A Requirements Analysis of the 2008 MILSATCOM Architecture," Master's Thesis, Naval Postgraduate School, September 1997.

Carlan, M.J., "A Future Space Intelligence Architecture," Master's Thesis, Naval Postgraduate School, September 1997.

Padget, S.A., "Issues in Space Law and Policy," Master's Thesis, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Sensors, Command, Control, and Communications, Electronics, Other (Space)

KEYWORDS: Satellite Digital Communications, Direct Sequence Spread Modulation, Over-the-Horizon Communications, Amateur Satellite, Thin-Film Ferroelectric Material

NAVAL SPACE SYSTEMS ACADEMIC CHAIR

Rudolf Panholzer, Professor

Craig Baldwin, Naval Space Systems Academic Chair

Space Systems Academic Group

Sponsor: Naval Space Command

OBJECTIVE: The incumbent of the Naval Space Systems Academic Chair engaged in instruction and research and act as consultants in the area of specialization to students and faculty of the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREA: Other (Space)

KEYWORDS: Satellite Digital Communications, Direct Sequence Spread Modulation, Over-the-Horizon Communications, Amateur Satellite, Thin-Film Ferroelectric Material

FERROELECTRICITY RESEARCH NEWSLETTER

Rudolf Panholzer, Professor

Space Systems Academic Group

Sponsor: Office of Naval Research

OBJECTIVE: A quarterly research newsletter designed to supply information on national and international symposia, conferences, workshops, and meetings which deal with topics of interest to scientists, engineers, and students in the field of integrated ferroelectrics research was produced quarterly.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structure

KEYWORDS: Integrated Ferroelectrics

SPACECRAFT DESIGN INSTRUCTION AND RESEARCH SUPPORT

Rudolf Panholzer, Professor

Space Systems Academic Group

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) facilities development for spacecraft design, development, and test.

PROJECT SUMMARIES SP

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Satellite Digital Communications, Direct Sequence Spread Spectrum Modulation, Over-the-Horizon Communications.

NEAR-EARTH-OBJECT INTERCEPTION

**I. Michael Ross, Associate Professor
Space Systems Academic Group
Sponsor: Johns Hopkins University**

OBJECTIVE: This proposal is for the purpose of analyzing certain problems associated with near-Earth-object interception. These problems need to be addressed today so that the United States and the world, at large, will be prepared to handle them when they occur tomorrow.

DoD KEY TECHNOLOGY AREA: Other (Space)

KEYWORDS: Space Warfare

**CENTER FOR RESEARCH INTO THE MILITARY APPLICATIONS OF SPACE
Alan Ross, Tactical Exploitation of National Capabilities (TENCAP) Chair Professor
Space Systems Academic Group
Sponsor: Naval Engineering Logistics Office**

OBJECTIVE: Funds are provided for the newly created center for research into the military application of space at NPS.

DoD KEY TECHNOLOGY AREA: Other (Space)

KEYWORDS: Military Applications of Space

PUBLICATIONS/PRESENTATIONS SP

CONFERENCE PAPERS

Agrawal, B., Song, G., and Buck, N., "Slew Maneuvers of Flexible Spacecraft Using Input Shaping and Pulse-Width Pulse-Frequency Modulated Thrusters," IAF-97-A.2.09, *Proceedings of the 48th International Astronautical Congress*, Turin, Italy, 6-10 October 1997.

Hutchins, R.G. and San Jose, A.P., IMM Tracking of a Theater Ballistic Missile during Boost Phase," Oliver Drumond, (ed.), *Proceedings of SPIE Signal and Data Processing of Small Targets*, Vol. 3373, pp. 528-537, 1998.

Michael, S., Shehata, K., and Fouts, D., "Analog/Digital Gallium Arsenide Circuits and Systems Design," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA, August 1997.

Michael, S., Shehata, K., and Fouts, D., "Dynamic Logic Families for Complementary Gallium Arsenide (CgaAs) Fabrication Processes," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA August 1997.

Michael, S. and Oldland, H., "A GaAs Mixed Mode Switched Capacitor VLSI," *Proceedings of the 40th Midwest Symposium on Circuits and Systems*, Sacramento, CA, August 1997.

Song, G., Buck, N., and Agrawal, B., "Spacecraft Vibration Using Pulse-Width Pulse Frequency Modulated Input Shaper," *Proceedings of AIAA Guidance, Navigation, and Control Conference*, New Orleans, LA, 11-13 August 1997.

CONFERENCE PRESENTATIONS

Hutchins, R.G. and San Jose, A.P., "IMM Tracking of a Theater Ballistic Missile during Boost Phase," SPIE Signal and Data Processing of Small Targets, Orlando, FL, April 1998.

Michael, S., "A GaAs Mixed Mode Switched Capacitor VLSI," 40th Midwest Symposium on Circuits and Systems, Sacramento, CA, August 1997.

1997 THESIS ABSTRACTS SP

A REQUIREMENTS ANALYSIS OF THE 2008 MILSATCOM ARCHITECTURE

David R. Bradley-Lieutenant, United States Navy

B.S., United States Naval Academy, 1990

Master of Science in Space Systems Operations-September 1997

Advisor: Donald v. Z. Wadsworth, Space Systems Academic Group

Second Reader: Alan Ross, Navy Tactical Exploitation of National Capabilities (TENCAP) Chair

The U.S. Navy is different from the other armed forces in its communications requirements. Due to the lack of terrestrial connectivity possessed by other services, the Navy has become highly reliant on SATCOM for all forms of communication. This thesis presents a requirements analysis of a proposed MILSATCOM architecture. The architecture, when fielded, will form the backbone for all U.S. military satellite communications. It is expected to be operational in the year 2008. The purpose of the study is to determine if the proposed architecture meets Naval communications requirements as defined in the Emerging Requirements Data Base (ERDB). In keeping with the stated purpose, only Naval requirements were loaded for the analysis. Requirements from other services and government agencies were not considered for this study.

As we enter the Information Age, communications connectivity and capacity will equate to operational effectiveness for Naval forces. This thesis identifies requirement shortfalls in the proposed architecture. It specifies the frequency bands where deficiencies are evident. It also proposes alternatives to fulfill or augment noted requirement shortfalls.

COBRA BRASS FOR BATTLESPACE CHARACTERIZATION AND BATTLE DAMAGE ASSESSMENT (U)

William Mitchell Darling-Lieutenant, United States Navy

B.S., Purdue University, 1986

Master of Science in Systems Technology-March 1997

Advisor: Dan C. Boger, Command, Control, and Communications Academic Group

Second Reader: Kyle T. Alfriend, Space Systems Academic Group

Battlespace characterization and battle damage assessment are important to the warfighter and must be a part of the strike planning. The Cobra Brass research and development sensor has the capability to provide information the warfighter can use to aid in his decision making. Navy TENCAP is using Cobra Brass in an operational mode to test the feasibility of operationally tasking this type of sensor. This thesis educates the warfighter on the Cobra Brass family of sensors, investigates the utility of Cobra Brass for battlespace characterization and battle damage assessment, and develops a concept of operations for the non-imaging infrared sensors presently deployed and for future such sensors.

SATISFYING NAVAL LOW DATA RATE MOBILE COMMUNICATION REQUIREMENTS

Sean P. Fuller-Lieutenant, United States Navy

B.S., United States Naval Academy, 1989

Master of Science in Space Systems Operations-September 1997

Advisor: Carl Jones, Department of Systems Management

Second Reader: Donald v. Z. Wadsworth, Space Systems Academic Group

In today's electronic age, the Department of Defense is relying more heavily on the transfer of information to maintain battlespace awareness and command and control efficiency. Current military satellite communication systems are unable to keep pace with the growing requirements for electronic transfer of voice, data, and video information. Additionally, these systems are expected to begin failing in the 2003 to 2007 timeframe with no identified replacement. Naval Forces consist of highly mobile units that often operate in harsh environments. New communication systems must be designed that can satisfy the needs of these mobile forces that cannot rely on secure landlines for the timely transfer of information.

This thesis first examines the process for developing requirements and how they relate to the military acquisition and system engineering processes. Established methods for documenting satellite communications requirements are also reviewed. Next, potential technological drivers for a system to satisfy the low data rate needs of tomorrow's Naval Forces are presented. Current systems and plans are examined to provide information on current capabilities. Following that, a set of

1997 THESIS ABSTRACTS SP

future architecture options and tradeoffs are presented to satisfy these mobile communications needs. Finally, conclusions and recommendations about the organizations and groups tasked with guiding the military and its use of space are provided.

THE ARMY TACTICAL COMMAND AND CONTROL SYSTEM

Mark A. Huron-Major, United States Army

B.S., Texas A&M University, 1984

Master of Science in Systems Technology-June 1997

Advisors: Donald van Z. Wadsworth, Space Systems Academic Group

Lt Col John H. Gibson, Command, Control, and Communications Academic Group

This thesis is a summary of the capabilities of the Army Tactical Command and Control System (ATCCS) and the guiding Command, Control, Communications, Computers and Intelligence (C4I) documents as they apply to the ATCCS. Its purpose is to strengthen the knowledge base of Army officers entering the Joint C4I curriculum by providing a summary of Joint and Army C4 doctrine and guidance as it applies to ATCCS.

ATCCS is the Army's primary Command and Control (C2) system at echelons corps and below. ATCCS consists of five smaller systems, each a Battlefield Functional Area Control System (BFACS) controlling seven Battlefield Functional Areas (BFA). The five BFACS are the Maneuver Control System (MCS), the Advanced Field Artillery Tactical Data System (AFATDS), the Forward Area Air Defense Command, Control and Intelligence System (FAAD C21), the Combat Service Support Control System (CSSCS), and the All Source Analysis System (ASAS).

A clear strategy for the functional design of ATCCS is supported by three documents. Related to and supportive of each other, the three documents are Joint Pub 6-0, Doctrine for Command, Control, Communications and Computer Systems Support to Joint Operations; The Army Enterprise Strategy consisting of The Vision and The Implementation Plan; and Army Field Manual 100-5, Operations. This thesis draws threads of continuity from joint doctrine through Army guidance into implementation in ATCCS.

THE DESIGN OF THE RADIO FREQUENCY (RF) SUBSYSTEM PRINTED CIRCUIT BOARDS FOR THE PETITE AMATEUR NAVY SATELLITE (PANSAT)

Carl Andrew Lahti-Lieutenant, United States NaRy

B.S.S.E., United States Naval Academy, 1989

Master of Science in Electrical Engineering-June 1997

Electrical Engineer-June 1997

Advisors: Randy Borchardt, Department of Electrical and Computer Engineering

Rudolf Panholzer, Space Systems Academic Group

The Petite Amateur Navy Satellite (PANSAT) is a small digital communication satellite being developed by the Space Systems Academic Group and the Naval Postgraduate School. This thesis describes the layout of the three final flight printed circuit boards for the radio frequency (RF) subsystem for PANSAT. The circuits and layouts are documented in detail. A link analysis is performed to verify system design and a power budget provided for integration with other satellite systems. Printed circuit board design fundamentals and high frequency printed circuit board construction techniques are also described.

1997 THESIS ABSTRACTS SP

AN OPERATIONAL OVERVIEW OF NATIONAL SIGINT COLLECTION (U)

William Ken Moreno-Lieutenant, United States Navy

B.S., United States Naval Academy, 1990

Master of Science in Space Systems Operations-September 1997

Advisor: Dan Boger, Command, Control, and Communications Academic Group

Second Reader: Bill Clifton, Space Systems Academic Group

National SIGINT collection remains both a national and fleet level priority. As such, a basic understanding of these collection systems is given emphasis at the Naval Postgraduate School for curriculums such as Space Systems Operations, Space Systems Engineering, and Information Warfare. Yet no one document or reference contains all relevant material for instruction of the subject, as taught at NPS. Also, most references do not present the material in a format readily assimilated by students with little or no experience in related fields.

This thesis is intended to produce a document which will provide an operational overview of all relevant national SIGINT collection systems. The primary product of this thesis is a hard copy paper which could be used both as a source for professors and as a reference for students studying national SIGINT collection. Operational usefulness, communications paths, and system differences are the primary topics of the paper. All topics will be researched with an operational, vice technical, consideration.

Additionally, a version of this operational overview has been placed on the INTELINK secure network. In the form of a web page (not unlike web pages found on the World Wide Web/Internet), the thesis then becomes a user-interactive learning tool. Users can visit the site, download relevant information, then follow hypertext links to related sites such as mission offices or reporting sites.

FINAL DESIGN, INTEGRATION, AND VALIDATION OF THE PANSAT ANTENNA SYSTEM

Gary J. Smilowitz-Lieutenant Commander, United States Navy

B.E.E.E., Vanderbilt University, 1985

Master of Science in Electrical Engineering-March 1997

Advisor: Richard W. Adler, Department of Electrical and Computer Engineering

Second Reader: Rudolf Panholzer, Space Systems Academic Group

In this thesis, the final design for the Petite Amateur Navy Satellite (PANSAT) antenna system is constructed, integrated, and validated. The antenna elements and matching network are field tested and compared to the Numerical Electromagnetics Code (NEC) model. The final free-space radiation pattern and its power gain distribution will be used to help track PANSAT's rotation during its orbit.

USSOCOM METRICS - A CASE STUDY IN MODERN C4I NETWORK MANAGEMENT ISSUES

Richard E. Stocking-Lieutenant Commander, United States Navy

B.A., University of Central Florida, 1981

Master of Science in Systems Technology-June 1997

Advisors: Gilbert M. Lundy, Department of Computer Science

Donald van Z. Wadsworth, Space Systems Academic Group

Modern Department of Defense C4I systems utilize high speed commercial computer networks, composed of commercial equipment and connectivity. The United States Special Operations Command (USSOCOM's) SCAMPI (not an acronym) Network was a forerunner of this trend. Industry uses the same type of circuits but approaches the network management of these circuits from a financial interest versus the military strategic and tactical aspects considered by the service user. This thesis analyzes this representative network in the context of industry network management and metrics practices. The thesis first surveys and explains the industry practices most prevalent in this changing environment and then examines the practices in place at USSOCOM. The compilation of industry-wide network management and metrics procedures is followed

1997 THESIS ABSTRACTS SP

by a series of solution recommendations for the SCAMPI network. These recommendations are explained in the context of current industry practices. This is followed by a series of emerging industry trends and technical developments which most likely will affect the implementation of network management and metrics tools. These developments are followed by a comprehensive industry definitions section, network bibliography, and a hypertext link guide to current military, industry and educational institutions networking solutions.

INTEGRATION OF COMMERCIAL MOBILE SATELLITE SERVICES INTO NAVAL COMMUNICATIONS

Cary Reese Stone-Lieutenant, United States Navy

B.S., University of Mississippi, 1992

Master of Science in Space Systems Operations-September 1997

Advisor: Brij Agrawal, Department of Aeronautics and Astronautics

Second Reader: Donald v. Z. Wadsworth, Space Systems Academic Group

Mobile Satellite Services (MSS) need to be integrated into Naval Communications. DoD SATCOM military-owned systems fall well short of meeting DoD SATCOM requirements in general and mobile SATCOM specifically. This thesis examines DoD SATCOM requirements, especially those affecting communications on the move. From these requirements, three systems—Inmarsat, Iridium and Globaistar—are identified and evaluated for potential use in Naval Communications. An overview of space communications and each of the three systems is provided to identify general operational capabilities, system strengths, and system weaknesses. The Naval narrowband functional requirements process is explored and DoD SATCOM and Commercial MSS ability to satisfy those requirements is assessed. Potential Naval MSS communications missions are examined and possible DoD enhancements are considered for each system as well as the impact these enhancements will have on each system. Recommendations are provided as to which Naval communications missions are best suited for these enhanced MSS.

**UNDERSEA WARFARE
ACADEMIC GROUP**

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GROUP SUMMARY UW

The Undersea Warfare Academic Group (USWAG) consists of ten faculty members plus the Curricular Officer. The faculty members teach in the USW curriculum and are responsible for its academic content. Members conduct USW-related research and serve as thesis advisors for USW students.

Associate Professor Steve Baker (Physics)
Professor Robert Bourke (Oceanography)
Assistant Professor Donald Brutzman (Undersea Warfare)
Professor Ching-Sang Chiu (Oceanography)
Professor James Eagle (Operations Research), Chair
Associate Professor Ralph Hippenstiel (Electrical and Computer Engineering)
Professor Tom Muir, Chair of Mine Warfare (IPA assignee from the University of Texas at Austin)
Professor James Sanders (Physics)
Associate Professor Clyde Scandrett (Mathematics)
Assistant Professor Kevin Smith (Physics)
CDR Mike McMaster, USW Curriculum Officer

An overview of research sponsored or co-sponsored by the USWAG is below.

Middle Atlantic Bight (Shelfbreak Primer) Field Study: Professor Ching-Sang Chiu continued to collaborate with Woods Hole Oceanographic Institution in the ONR-sponsored Middle Atlantic Bight Field Study. The overall goal is to understand the propagation of sound from the continental slope to the continental shelf, including the effects of shelf-break frontal features and seasonal stratification. In particular, one major goal is to obtain a high resolution description of the spatial and temporal evolution of the shelf-break front and to clarify the mechanisms by which eddies are formed.

Data Analysis for the Shallow Water Acoustics in a Random Medium (SWARM) Experiment: Professor Ching-Sang Chiu continued evaluation of data collected by two upward-looking Acoustic Doppler Current Profilers deployed as part of the multi-institutional SWARM study. The objective of this research is to characterize the internal waves and their impact on the spatial and temporal variability and coherence of acoustic transmissions in a shelf environment.

Monitoring Whales Using the Pt. Sur Acoustic Array – A Feasibility Study: Professors Ching-Sang Chiu and Curtis Collins collaborated to: (1) investigate the feasibility of locating and tracking distant California blue whales using a former SOSUS array and matched signal algorithms; (2) explore the possibility of providing supplementary information on counts and transit paths of California blue whales; and (3) enhance the understanding of low-frequency sound propagation physics in a littoral environment.

International Conference in Shallow-Water Acoustics: Professor Ching-Sang Chiu continued work toward the long-term goal of formulating and conducting a collaborative international experiment in the seas of China. Such an experiment will focus on studying the physics and variability of sound propagation and scattering that are unique to the coastal waters of the Asian Pacific region. The FY97 objective was to promote scientific exchange and establish a dialog between Asian and U.S. scientists who are active in shallow-water acoustics research.

Development of the Pt. Sur Ocean Acoustic Observatory: Professor Chiu continued his work to preserve the functionality of the Pt. Sur SOSUS horizontal hydrophone array and toward the conversion of the facility into a dual-use Ocean Acoustic Observatory for undersea research. In 1997, the development of the Pt. Sur Ocean Acoustic Observatory (OAO) was continued using reimbursable funding provided by SAIC, Cornell University, and the Office of Naval Research. The 1997 OAO research projects include nuclear test ban treaty monitoring, coastal ocean circulation studies, and marine mammal studies. The latest accomplishment is the development of a full-array classified data archival capability. This enhanced capability will enable the conduct of both classified and unclassified research that requires spatial beamforming using the horizontal array.

GROUP SUMMARY UW

Rapidly Reconfigurable Virtual Environment Network Protocols: Assistant Professor Don Brutzman and Professor Mike Zyda are creating a formally specifiable behavior protocol that permits scalable inter-entity interactions to be defined, modified, and tested while large-scale exercises are in progress.

Tactical Visualization of the Environment: Manta Minefield Search: Assistant Professor Don Brutzman has been working with the Naval Undersea Warfare Center, Newport, Rhode Island, on the Manta submarine-launched underwater vehicle program. The purpose of Professor Brutzman's project is to demonstrate how tactical visualization of real-world environments can provide significant insights into robot system development and tactical deployment.

Autonomous Underwater Vehicle (AUV) Development: Assistant Professor Don Brutzman and Professor Anthony Healey and thesis students are attempting to solve open problems in underwater vehicle control to allow the docking of an AUV with a tube in the presence of time-varying turbulent flow fields.

Mine Countermeasures Program: Professor Tom Muir occupied the Chair of Mine Warfare and provided overall coordination of mine warfare-related activities at NPS. This included planning the weekly Menneken Lecture Series on Mine Warfare and coordinating preparations for and executing a major mine warfare symposium to be held at NPS in April 1998.

Surf Zone Seismo Acoustics: Professor Tom Muir and Associate Professor Steve Baker have continued working on the concept of using of an active, seismic sonar for the detection of mines buried in the surf zone. Electromechanical transducers having two, controllable degrees of freedom were developed to selectively excite seismic interface waves that travel along the air or water boundary with the sediments. These interface waves were caused to reflect off buried mines, and the received echoes were detected in such a way as to determine the range and bearing of the buried targets from the sonar.

PROJECT SUMMARIES UW

TACTICAL VISUALIZATION OF THE ENVIRONMENT: MANTA MINEFIELD SEARCH

Don Brutzman, Assistant Professor

Undersea Warfare Academic Group

Anthony Healey, Professor

Department of Mechanical Engineering

Center for Autonomous Underwater Vehicle Research

Sponsor: Naval Undersea Warfare Center-Newport

OBJECTIVE: The purpose of this project is to demonstrate how tactical visualization of real-world environments can provide significant insights into robot system development and tactical deployment.

SUMMARY: To illustrate the power of tactical visualization, Manta robot submarines are shown how they might bring new and needed capabilities to the fleet. A meaningful tactical scenario was developed around four Manta robots being deployed from a host submarine. A scalable Web-based approach to 2D and 3D visualization is presented using the Hypertext Modeling Language (HTML) and the Virtual Reality Modeling Language (VRML). Extensive analytic simulation of multiple tactics versus multiple minefield types provides a useful methodology and tangible minefield mapping results for robots. Finally, utilizing an underwater virtual world and existing robot software for the NPS *Phoenix* autonomous underwater vehicle (AUV) ensures that all results are feasible using today's technology. Ongoing unfunded work includes a Java-VRML library for real-time 3D visualization of sonar beams.

CONFERENCE PRESENTATION:

Brutzman, D.P., Chan, E., Evans, M., Holliday, T., Huck, M., Jezek, R., Ma, B.-B., Murley, S., Toland, R., and Yee, Y., "Minefield Search Tactic Evaluation Using Four Autonomous Manta UUVs," Symposium on Technology and the Mine Problem, Naval Postgraduate School, Monterey CA, 6-10 April 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Tactical Visualization, Manta Submarines, Virtual Worlds, AUV, Minefield Search

AUTONOMOUS UNDERWATER VEHICLE (AUV) DEVELOPMENT

Don Brutzman, Assistant Professor

Undersea Warfare Academic Group

Anthony Healey, Professor

Department of Mechanical Engineering

Center for Autonomous Underwater Vehicle Research

Sponsor: Unfunded

OBJECTIVE: To solve open problems in underwater vehicle control to dock an AUV with a tube in the presence of time-varying turbulent flow fields.

SUMMARY: Algorithms have been developed and tested for sensing, maneuvering, and precise control relative to a docking station. Sensing and maneuverability have been demonstrated in the presence of turbulent cross-body flow using the AUV virtual world. This effort addresses a significant problem facing AUVs where success has broad implications. Distributed analog/digital device control using the LONTALK protocol has also been demonstrated. An ongoing dialog with researchers in the French Navy has proven productive, with graduate students visiting and working at NPS.

PROJECT SUMMARIES UW

PUBLICATION:

Brutzman, D., Healey, A., Marco, D., and McGhee, R., "The *Phoenix* Autonomous Underwater Vehicle," *AI-Based Mobile Robots*, eds: David Kortenkamp, Pete Bonasso and Robin Murphy, MIT/AAAI Press, Cambridge MA, 1998.

CONFERENCE PRESENTATION:

Brutzman, D., "Tutorial: Virtual World for an Autonomous Underwater Vehicle (AUV)," IEEE Oceanic Engineering Society Conference OCEANS 97, Halifax Nova Scotia, October 1997.

THESIS DIRECTED:

Young, F.C., "Phoenix Autonomous Underwater Vehicle (AUV): Networked Control of Multiple Analog and Digital Devices Using LONTALK," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft, Modeling and Simulation, Sensors, Computing and Software

KEYWORDS: Autonomous Underwater Vehicle, Robot, AUV, Control, Virtual Worlds

RAPIDLY RECONFIGURABLE VIRTUAL ENVIRONMENT NETWORK PROTOCOLS

Don Brutzman, Assistant Professor
Undersea Warfare Academic Group
Michael Zyda, Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: To create a formally specified behavior protocol that permits scalable inter-entity interactions to be defined, modified, and tested while large-scale exercises are in progress.

SUMMARY: Construction of a Distributed Interactive Simulation (DIS) library in the *Java* language has been continued and hooks are being created to generic 3D scenes drawn using the Virtual Reality Modeling Language (VRML). Completed thesis work shows how to formally specify protocol data unit (PDU) elements and subsequently autogenerate reader/writer source code. The new DIS library will be extended to permit on-the-fly modification in mid-exercise, permitting experimental optimization of behavior protocols and overcoming a key DIS deficiency. This functionality will be implemented as Area of Interest Manager (AOIM) applets or agents (i.e., mobile executable code) which consolidates multicast channel selection, subscription and desubscription of network streams, either for individual hosts or local-area networks (LANs). This is an ongoing project, which also supports the virtual reality transfer protocol (vrtp) research.

PUBLICATIONS:

Brutzman, D., "Graphics Internetworking: Bottlenecks and Breakthroughs," Chapter, *Digital Illusions*, ed: Clark Dodsworth, Addison-Wesley, Reading Massachusetts, 1997.

Rhyne, T.-M., Brutzman, D., and Macedonia, M., "Internetworked Graphics and the Web," *IEEE COMPUTER*, Vol. 30, No. 8, pp. 99-101, August 1997.

PROJECT SUMMARIES UW

CONFERENCE PRESENTATION:

Brutzman, D., Zyda, M., Watsen, K., and Macedonia, M., "Virtual Reality Transfer Protocol (vrtp) Design Rationale," Workshops on Enabling Technology: Infrastructure for Collaborative Enterprises (WET ICE): Sharing a Distributed Virtual Reality, Massachusetts Institute of Technology, Cambridge MA, 18-20 June 1997.

OTHER:

McGregor, D. and Brutzman, D., *DIS-Java-VRML Working Group*.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Large-Scale Virtual Environments (LSVEs), Network Protocols, Multicast, DIS

DATA ANALYSIS FOR THE SWARM EXPERIMENT

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this research is to characterize the internal waves and their impact on the spatial and temporal variability and coherence of acoustic transmissions in a shelf environment.

SUMMARY: During the summer of 1995, a multi-institutional field study called Shallow Water Acoustics in a Random Medium (SWARM) was conducted in the Mid-Atlantic Bight continental shelf region off the coast of New Jersey. Environmental and acoustic sensors were deployed as part of SWARM to measure and characterize the non-linear internal waves and their impact on the spatial and temporal coherence of the acoustic transmissions. As part of the environmental monitoring network, two bottom-moored, upward-looking Acoustic Doppler Current Profilers (ADCPs) were deployed. An oceanographic, modal, time-series analysis of the ADCP data reveals that: large-amplitude, nonlinear, internal wavepackets were generated at multiple sites near the shelfbreak; the generation mechanism was consistent with the lee-wave hypothesis of generation; the propagation characteristics were in good agreement with nonlinear soliton theory; and the power spectral density was spatially varying and changed markedly during the passage of these nonlinear waves. Based on these observations, a model of the induced sound-speed perturbations was developed. Using a coupled normal-mode propagation model, the temporal and vertical structure of the sound field were subsequently calculated for comparison to data obtained by a vertical line array.

PUBLICATIONS:

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating the Properties of the Sound Field in a Shelf Region near the Shelfbreak," *Proceedings of the 6th Western Pacific Regional Acoustics Conference*, Vol. 1, pp. 329-334, 1997.

Apel, J., Badiey, M., Chiu, C.-S., Finnerte, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., Wolf, S., "An Overview of the 1995 SWARM Shallow Water Internal Wave Acoustic Scattering Experiment," *IEEE Journal of Oceanic Engineering*, 22(3), 465-500, 1997.

CONFERENCE PRESENTATIONS:

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating Properties of the Sound Field in a Shelf Region near the Shelfbreak," 6th Western Pacific Regional Acoustics Conference, Hong Kong, 19-21 November, 1997.

PROJECT SUMMARIES UW

Apel, J., Badiey, M., Chiu, C.-S., Finnerte, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., Wolf, S., "The New Jersey Shelf Shallow-Water Acoustic Random Media Propagation Experiment (SWARM)," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Apel, J., Chiu, C.-S., Headrick, R., Lynch, J., Orr, M., Pasewark, B., and Wolf, S., "Acoustic Travel Time and Intensity Fluctuations Measured in the 1995 SWARM Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

THESIS DIRECTED:

Ng, S.-L., "A Simulation Study of Acoustic Variability due to Internal Solitary Waves on the Mid-Atlantic Continental Shelf," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Littoral, Acoustics, Internal tides, Internal waves

MIDDLE ATLANTIC BIGHT (SHELFBREAK PRIMER) FIELD STUDY

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVES: The objectives of this multi-year, multi-institutional field study in the Middle Atlantic Bight are to improve the understanding of the physical variability of the shelf break front south of New England, and to apply this improved knowledge to problems in acoustical propagation. To do this, detailed measurements have been made of physical and acoustical properties during the contrasting summer and winter seasons. These measurements are being related to physical and acoustical modeling studies. Results from these modeling efforts, tested against the observations, should be broadly applicable to shelf-break regions on a more global basis.

SUMMARY: The field programs surveying the frontal region have been concluded. The field work included two intensive three-week experiments, one in July 1996 (summer) and the other one in February 1997 (winter). Specifically, each of the two experiments successfully employed a suite of observational techniques including an acoustic tomography array consisting of multiple transceivers/sources and two vertical hydrophone arrays (VLAs) straddling the shelf-break front, several high-resolution, three-dimensional surveys of the frontal region with a SeaSoar, a shelf-to-slope hydrographic section, and moored arrays of ADCPs, current meters and thermistors. The resultant data set is both comprehensive and of high quality, and will allow for gaining fundamental insights into the oceanographic processes which influence acoustic propagation in a slope-shelf region. The measurements are being supplemented by model studies, both oceanographic and acoustic. The detailed analysis of the data and the modeling has begun in earnest, with an initial emphasis being upon understanding the oceanographic field through which the acoustic signals have propagated.

NPS plays a lead role in all phases of the study including experimental planning, data collection, data processing, acoustic modeling, and data analysis. Specifically, NPS has initiated modal processing, modeling, and time-series analysis of the acoustic data in an effort to quantify the dominant space and time scales of the variability in the sound field and to relate the observed acoustic variability to ocean processes.

PUBLICATIONS:

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," *IEEE Journal of Oceanic Engineering*, 22(3), 522-533, 1997.

PROJECT SUMMARIES UW

Lynch, J.F., Gawarkiewicz, G.G., Chiu, C.-S., Pickart, R., Miller, J.H., Smith, K.B., Robinson, A., Brink, K., Beardsley, R., Sperry, B., and Potty, G., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Mid-Atlantic Bight," *Proceedings of the International Conference on Shallow-Water Acoustics*, Beijing, China, 1997, in press.

CONFERENCE PRESENTATIONS:

Chiu, C.-S. and Lynch, J. F., "Acoustic Tomography in Shallow Water," International Workshop on Ocean Acoustic Tomography, Yokosuka, Japan, 13-14 March 1997.

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," 3rd International Conference on Theoretical and Computational Acoustics, Newark, NJ, 14-18 July 1997.

Chiu, C., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December 1997.

Gawarkiewicz, G.G., Pickart, R., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

Beardsley, R.C., Brink, K.H., Caruso, M.J., Chiu, C.-S., Gawarkiewicz, G.G., Lynch, J.F., Miller, J.H., Pickart, R., Robinson, A.R., and Smith, K.B., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Middle Atlantic Bight," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Littoral, Acoustics, Nowcast, Shelfbreak Fronts

MONITORING WHALES USING THE PT. SUR ACOUSTIC ARRAY - A FEASIBILITY STUDY

Ching-Sang Chiu, Associate Professor

Curtis A. Collins, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVES: The objectives include: (1) to investigate the feasibility of locating and tracking distant California blue whales using a former SOSUS array and matched signal algorithms; (2) to explore the possibility of providing supplementary information on counts and transit paths of California blue whales; and (3) to enhance the understanding of low-frequency sound propagation physics in a littoral environment.

SUMMARY: Detecting, classifying, localizing, and tracking vocalizing whales using receiver arrays at long ranges is a complex problem. It is a combined signal processing-acoustics-oceanography problem. First, knowledge of the loudness and frequency-time distribution of the different whale sounds is required for classification purposes. Equally important is the understanding of the basic structure and variability of the ocean sound channel. The ocean scrambles the vocalized signal by its multipaths as the signal propagates to a distant receiver. The ability to predict the mean and variance of the propagation is thus required to unscramble the received signal and to constrain the uncertainty.

In the summer of 1997, two three-day experiments were conducted to test the feasibility of acoustically detecting, classifying, localizing, and tracking blue whales at long ranges using a former SOSUS listening array located at the Naval Postgraduate School Ocean Acoustic Observatory (OAO) at Pt. Sur, CA. During each experiment, full-array data were archived continuously at the OAO. In concert with the shore-based acoustic monitoring, an aircraft was assigned to locate blue whales in the Monterey Bay National Marine Sanctuary and to direct a research vessel to a whale site. The research vessel was manned with observers and instrumented with a towed hydrophone array to ground-truth the locations of the

PROJECT SUMMARIES UW

blue whales and classify the vocalized near-field signals. These shipboard measurements were required to provide a means to separate the source signal characteristics from the multipath signatures for the calibration and validation of broadband, model-based localization methods. Initial experimental as well as modeling results show great promise, which included assessments of the predictability, i.e., variability, of the vocalized sound and the uniqueness of the location-dependent multipath structure. Both are fundamental to the applicability of model-based algorithms.

CONFERENCE PRESENTATION:

Chiu, C.-S., Collins, C.A., Hager, C.A., Miller, C.W., Moore, T.C., Rocheleau, M.R., Lashkari, K., and Hayes, S., "A Feasibility Field Study of Monitoring Blue Whales Using the Pt. Sur Ocean Acoustic Observatory," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December, 1997.

THESIS DIRECTED:

Hager, C.A., "Modeling the Performance of the Pt Sur Hydrophone Array in Localizing Blue Whales," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Coastal, Acoustics, Whale Monitoring, Alternate Uses

INTERNATIONAL CONFERENCE IN SHALLOW-WATER ACOUSTICS

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVES: The long-term goal is to formulate and conduct a collaborative international experiment in the seas of China. Such an experiment will focus on studying the physics and variability of sound propagation and scattering that are unique to the coastal waters of the Asian Pacific region. The FY97 objective was to promote scientific exchange and establish a dialog between Asian and U.S. scientists who are active in shallow-water acoustics research.

SUMMARY: The approach was to hold an international conference in Beijing, China as a outgrowth from the Office of Naval Research (ONR) USA-China Conference in Shallow-Water Acoustics held at the Naval Postgraduate School in December 1995. An international conference in China could attract many of the top-notch Asian scientists to attend. It could help to establish a dialog between the Asian and U.S. underwater acoustics communities and to provide a forum to exchange and discuss the latest scientific ideas, approaches and results in shallow-water acoustics which might form the basis for future collaborative research efforts between the U.S. and Asian communities.

The Principal Investigator worked closely with the Chinese co-organizers to coordinate the conference logistics, to plan the conference agenda, and co-chair the technical committee, to assist in identifying topics for special sessions, to select invited speakers and session chairs, and to assign contributed papers to the appropriate sessions. He also served on an ONR delegation to visit several oceanographic and acoustic laboratories in China following the conference. The post-conference tour was designed to begin the development of an international steering group to formulate and execute a collaborative field study.

A major accomplishment is that the conference and the post-conference tour have led to a strong dialog with the Chinese, Japanese, Korean, Singaporean, Russian and Indian scientists. An international steering group workshop to investigate the scientific, engineering, and logistic rationales that might form the basis for a collaborative international experiment in the seas of China is now in the planning.

PROJECT SUMMARIES UW

PUBLICATION:

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," *Proceedings of the International Conference on Shallow-Water Acoustics*, 1997, in press.

CONFERENCE PRESENTATION:

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," *International Conference on Shallow-Water Acoustics*, Beijing, China, 21-25 April 1997

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: Shallow-Water Acoustics

DEVELOPMENT OF THE PT. SUR OCEAN ACOUSTIC OBSERVATORY

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsors: Scientific AI Corporation, Cornell University, and Office of Naval Research

OBJECTIVES: The objectives are: (1) to preserve the functionality of the Pt. Sur SOSUS horizontal hydrophone array and (2) to convert the facility into a dual-use Ocean Acoustic Observatory for the purpose of undersea research.

SUMMARY: In 1995, the Pt. Sur Ocean Acoustic Observatory in the Monterey Bay National Marine Sanctuary was established for the purpose of undersea research. Several sponsoring organizations have contributed greatly to this commendable community effort. Their contributions were in terms of hardware, reimbursable funding for electric and electronic maintenance, labor, and the conduct of high-quality research using the data.

In 1997, the development of the Pt. Sur Ocean Acoustic Observatory (OAO) was continued using reimbursable funding provided by SAIC, Cornell University, and the Office of Naval Research. The 1997 OAO research projects include nuclear test ban treaty monitoring, coastal ocean circulation studies, and marine mammal studies. The latest accomplishment is the development of a full-array classified data archival capability. This enhanced capability will enable the conduct of both classified and unclassified research that require spatial beamforming using the horizontal array.

THESES DIRECTED:

Morvillez, T., "Monitoring Temperature Variability Along the California Coast Using Acoustic Tomography," Master's Thesis, Naval Postgraduate School, September 1997.

Smith, A., "Analysis of Modal Travel Time Variability due to Ocean Mesoscale Structure," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environment)

KEYWORDS: SOSUS, Alternate Uses, Acoustic Observatory

PROJECT SUMMARIES UW

SURF ZONE SEISMO ACOUSTICS

Thomas Muir, Chair of Mine Warfare

Undersea Warfare Academic Group

Stephen Baker, Associate Professor

Department of Physics

Sponsor: Office of Naval Research

OBJECTIVE: To provide the U.S. Navy and Marine Corps with a seismic sonar technology which will enable the detection of enemy mines that are buried in sea floor and beach sediments. This work is a continuation of prior research conducted by the senior principal investigator at the Laboratory of the NATO Supreme Atlantic Commander's Undersea Research Centre in La Spezia Italy and at the Applied Research Laboratory of the University of Texas at Austin. This research was ported to NPS in 1997, when Professor Muir became the Ellis A. Johnson Chair Professor of Mine Warfare. This work was originally sponsored by NATO, then transitioned to the ONR basic research program, and has now transitioned to ONR's exploratory research program, both in ONR Code 321 under Program Managers Dr. Jeffrey Simmen and Dr. Douglas Todoroff, respectively.

SUMMARY: The concept of an active, seismic sonar for the detection of mines buried in the surf and near surf zone was investigated. Electromechanical transducers having two, controllable degrees of freedom were developed to selectively excite seismic interface waves that travel along the air or water boundary with the sediments. These interface waves were caused to reflect off buried mines, and the received echoes were detected in such a way as to determine the range and bearing of the buried targets from the sonar. Signal processing of the seismic echo fields were developed to enhance the received target echoes and suppress the noise and reverberation. These procedures were tested in experiments done at the beach across from the Naval Postgraduate School.

PUBLICATIONS:

Muir, T.G., et al., "Seismic Interface Wave Sonar," *Proceedings of the Third Technological Conference of Underwater Acoustics*, The Institute of Marine Research of the Brazilian Navy, Ilha do Governador, Rio de Janeiro, Brazil, 23-24 September 1997.

Muir, T.G., et al., "Experiments on the Seismic Detection of Buried Objects," *Journal of the Acoustical Society of America*, American Physical Society, December 1997, accepted for publication.

CONFERENCE PRESENTATION:

Muir, T.G., "Seismic Interface Wave Sonar," Third Technological Conference of Underwater Acoustics, Institute of Marine Research of the Brazilian Navy, Ilha do Governador, Rio de Janeiro, Brazil, 23-24 September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Mine Warfare)

KEYWORDS: Mine Detection, Seismic Sonar

SUBMARINE SECURITY

Alan R. Washburn, Professor

James Eagle, Professor

Undersea Warfare Academic Group

Sponsor: Office of Naval Research

OBJECTIVE: This project is to familiarize the principal investigators and other NPS faculty with submarine security issues, the intention being to effect a more intense cooperation in future years. Travel to Johns Hopkins University/Applied

PROJECT SUMMARIES UW

Physics Laboratory (JHU/APL) is intended as a first step. Other efforts include support in defining the problem, developing or identifying analytic approaches, reviewing studies, and conducting independent studies. The principal investigators have extensive experience in systems studies involving submarines, particularly where search theory is involved.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Submarine, Security, Effectiveness

PUBLICATIONS/PRESENTATIONS UW

JOURNAL PAPERS

Apel, J., Badiy, M., Chiu, C.-S., Finnette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., and Wolf, S., "An Overview of the 1995 SWARM Shallow Water Internal Wave Acoustic Scattering Experiment," *IEEE Journal of Oceanic Engineering*, 22(3), 465-500, 1997.

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," *IEEE Journal of Oceanic Engineering*, 22(3), 522-533, 1997.

Rhyne, T.-M., Brutzman, D., and Macedonia, M., "Internetworked Graphics and the Web," *IEEE COMPUTER*, Vol. 30, No. 8, pp. 99-101, August 1997.

CONFERENCE PAPERS

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating the Properties of the Sound Field in a Shelf Region near the Shelfbreak," *Proceedings of the 6th Western Pacific Regional Acoustics Conference*, Vol. 1, 329-334, 1997.

Muir, T.G., et al, "Seismic Interface Wave Sonar," *Proceedings of the Third Technological Conference of Underwater Acoustics*, The Institute of Marine Research of the Brazilian Navy, Ilha do Governador, Rio de Janeiro, Brazil, 23-24 September 1997.

CONFERENCE PRESENTATIONS

Apel, J., Badiy, M., Chiu, C.-S., Finette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heydt, K., and Wolf, S., "The New Jersey Shelf Shallow-Water Acoustic Random Media Propagation Experiment (SWARM)," *International Conference on Shallow-Water Acoustics*, Beijing, China, 21-25 April 1997.

Apel, J., Chiu, C.-S., Headrick, R., Lynch, J., Orr, M., Pasework, B., and Wolf, S., "Acoustic Travel Time and Intensity Fluctuations Measured in the 1995 SWARM Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

Brutzman, D., "Tutorial: Virtual World for an Autonomous Underwater Vehicle (AUV)," *IEEE Oceanic Engineering Society Conference OCEANS 97*, Halifax, Nova Scotia, October 1997.

Beardsley, R.C., Brink, K.H., Caruso, M.J., Chiu, C.-S., Gawarkiewicz, G.G., Lynch, J.F., Miller, J.H., Pickart, R., Robinson, A.R., and Smith, K.B., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Middle Atlantic Bight," *International Conference on Shallow-Water Acoustics*, Beijing, China, 21-25 April 1997.

Brutzman, D.P., Chan, E., Evans, M., Holliday, T., Huck, M., Jezek, R., Ma, B.-B., Murley, S., Toland, R., and Yee, Y., "Minefield Search Tactic Evaluation Using Four Autonomous Manta UUVs," *Symposium on Technology and the Mine Problem*, Monterey CA, 6-10 April 1998.

Brutzman, D., Zyda, M., Watsen, K., and Macedonia, M., "Virtual Reality Transfer Protocol (vrtp) Design Rationale," *Workshops on Enabling Technology: Infrastructure for Collaborative Enterprises (WETICE): Sharing a Distributed Virtual Reality*, Massachusetts Institute of Technology, Cambridge MA, 18-20 June 1997.

Chiu, C.-S., Lynch, J.F., Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., Smith, K.B., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December 1997.

PUBLICATIONS/PRESENTATIONS UW

Chiu, C.-S. and Lynch, J. F., "Acoustic Tomography in Shallow Water," International Workshop on Ocean Acoustic Tomography, Yokosuka, Japan, 13-14 March 1997.

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating Properties of the Sound Field in a Shelf Region Near the Shelfbreak," 6th Western Pacific Regional Acoustics Conference, Hong Kong, 19-21 November, 1997.

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," 3rd International Conference on Theoretical and Computational Acoustics, Newark, NJ, 14-18 July 1997.

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Method and Experimental Results," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Chiu, C.-S., Collins, C.A., Hager, C.A., Miller, C.W., Moore, T.C., Rocheleau, M.R., Lashkari, K., and Hayes, S., "A Feasibility Field Study of Monitoring Blue Whales Using the Pt. Sur Ocean Acoustic Observatory," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December, 1997.

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Denner, W.W. and Chiu, C.-S., "A Report on the Joint U.S.-China Conference on Shallow-Water Acoustics," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Gawarkiewicz, G.G. Pickart, R., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

Muir, T.G., "Seismic Interface Wave Sonar," Third Technological Conference of Underwater Acoustics, Institute of Marine Research of the Brazilian Navy, Ilha do Governador, Rio de Janeiro, Brazil, 23-24 September 1997.

TECHNICAL REPORTS

Chiu, C.-S. and Denner, W.W., "Report of the Office of Naval Research USA-China Conference on Shallow-Water Acoustics," Naval Postgraduate School Technical Report, NPS-OC-97-001, January 1997.

BOOK CHAPTER

Brutzman, D., "Graphics Internetworking: Bottlenecks and Breakthroughs," Chapter, *Digital Illusions*, ed: Clark Dodsworth, Addison-Wesley, Reading, MA, 1997.

1997 THESIS ABSTRACTS UW

OPTIMIZING AEROBOT EXPLORATION OF VENUS

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Master of Science in Operations Research-March 1997

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: James N. Eagle, Undersea Warfare Academic Group

Venus Flyer Robot (VFR) is an aerobot—an autonomous balloon probe—designed for remote exploration of Earth's sister planet in 2003. VFR's simple navigation and control system permits travel to virtually any location on Venus, but it can survive for only a limited duration in the harsh Venusian environment. To help address this limitation, the following was developed: (1) a global circulation model that captures the most important characteristics of the Venusian atmosphere; (2) a simple aerobot model that captures thermal restrictions faced by VFR at Venus; and (3) one exact and two heuristic algorithms that, using abstractions (1) and (2), construct routes making the best use of VFR's limited lifetime. This modeling was demonstrated by planning several small example missions and a prototypical mission that explored numerous interesting sites recently documented in the planetary geology literature.

INTERNETWORKING: AIRBORNE MINE COUNTERMEASURES C41 INFORMATION SYSTEMS

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B.S., United States Naval Academy, 1988

Master of Science in Information Technology Management-December 1996

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Rex A. Buddenberg, Department of Systems Management

Airborne Mine Countermeasures (AMCM) Command Control Communication Computer and Intelligence (C41) baseline currently consists of stand-alone tactical decision aids. Information such as aircraft position, equipment status, and abbreviated mine like contact reports cannot be transferred in any form other than voice from/to the MH-53E helicopters while conducting Airborne Mine Countermeasures operations. There are currently no methods to transfer sonar video or single-frame imagery of mine-like objects between any Mine Warfare (MIW) units in a near-real time manner. Delays lasting several hours are frequently encountered before the results of a "rapid reconnaissance" airborne minehunting mission are made available to the rest of the fleet and/or MIW community. In order to improve command and control, the AMCM Mine Warfare community must integrate all of its C41 assets onto a tactical internet.

This thesis presents a tactical internet for AMCM with an open, standards-based modular architecture. It is based on the TCP/IP network model using common protocols and interfaces. Command and control will significantly improve as this network will provide a methodology to transfer critical information between AMCM C41 assets and tactical networks worldwide. Results from a comprehensive laboratory prototype demonstration using commercial off-the-shelf (COTS) equipment are presented along with lessons learned. Laboratory results show that this system works and can be deployed for testing at sea.

1997 THESIS ABSTRACTS UW

REALISTIC INTERFACE AND CONTROL OF A VIRTUAL SUBMARINE MODEL IN NPSNET

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B.S., University of Idaho, 1990**

Master of Science in Computer Science-March 1997

Advisors: Michael J. Zyda, Department of Computer Science

John S. Falby-Department of Computer Science

Donald Brutzman, Undersea Warfare Academic Group

The current NPSNET submarine simulator is not a viable training tool because it utilizes a control panel which runs as a separate process and includes three separate tabs, one each for the Officer of the Deck, Helm, and Weapons Officer. Besides lacking immersion qualities, most of the control icons and prototypes are not functional.

Our approach is to mount human entities to the submarine that can control and maneuver the submarine entity by interacting with various objects onboard the submarine. These human entities represent key members of the submarine control party including the Officer of the Deck, Diving Officer of the Watch, Chief of the Watch, Helmsman, Planesman, and a second Planesman. The submarine model was improved by building a 3D Control Room and adding manipulable visual cues to represent an actual submarine control room.

As a result of this work, a group of human entities can operate a submarine in NPSNET, acting together as a watch team and maneuvering the submarine through the virtual environment. Realism has been improved by immersing a user into the virtual environment as a virtual human entity.

ANALYSIS AND COMPARISON OF SEVERAL MEASURES OF PERFORMANCE FOR PASSIVE SONAR DETECTION SYSTEMS

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M.A., Old Dominion University, 1993

Master of Science in Operations Research-September 1997

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Second Reader: Donald P. Gaver, Department of Operations Research

This thesis is motivated by a debate at Commander, Operational Test and Evaluation Force (COTF) concerning which Measure of Performance (MOP) would be best to use when evaluating passive sonar detection systems. COTF has used probability of detection and Figure of Merit in the past, but probability of detection as a function of lateral range is being promoted in a recent Program Executive Officer for Undersea Warfare instruction. This thesis presents a menu of potential MOPs, their definitions, methods for calculating each MOP, relationships that exist between them, and a critique of their strengths and weaknesses as evaluation MOPs. Important MOP attributes are summarized for all listed MOPs to aid in MOP selection. The thesis looks in depth at the relationship between two of these MOPs which could make calculation of the more complex measure somewhat easier. Upper and lower limits for lateral range in terms of cumulative probability of detection are established. As a final step, the thesis involves a critical analysis of an existing computer program, which computes an approximation of a lateral range curve given a list of achieved detection ranges. A recommendation is made concerning use of this program.

1997 THESIS ABSTRACTS UW

EVALUATING COLOR FUSED IMAGE PERFORMANCE ESTIMATORS

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Master of Science in Operations Research-September 1997

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This thesis evaluated the effectiveness of sensor fusion—combining infrared and low-light-level imagery—to improve the F/A-18-target standoff range requirement. Several human performance studies have shown inconsistent results regarding the benefits of color-fused imagery. One method to test the validity of sensor fusion is to use mathematical models that simulate and predict the detection abilities of the human visual system. The mathematical models are derived quantitatively from the image statistics, while the behavior data are a qualitative measure of a human observer. This thesis developed a statistical analysis to compare and contrast these techniques to assess sensor fusion. The four models evaluated were: a Global matched filter, a Local matched filter, a Template matching filter, and a contrast-base image quality metric. Of the four models, the global matched filter produced the highest degree of correlation with the human data. The Global matched filter moderately predicted which of the single-band sensors and which of the fused sensors provided the higher sensitivities despite the characteristically different scenes. Although there are many refinements that need to be explored, the global matched filter concept may be used to evaluate and compare the many different fusion algorithms being proposed.

ROBOT WARS SIMULATION

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Donald Brutzman, Undersea Warfare Academic Group

Naval Postgraduate School (NPS) Combat Systems students learn about robots and autonomous weapons during group design projects in the SE 3015 course sequence. This sequence is designed to provide experience in combat systems development. The capstone project is the Robot Wars Competition, where pairs of student-designed autonomous robots battle each other. This thesis extends this competition into the arena of simulation and modeling. Our motivation is to further students' understanding of the strengths and weaknesses of computer modeling and simulation in combat systems design and testing.

This thesis creates a simulation foundation of the Robot Wars Competition. The simulation has been designed in two main parts, a C++ program that manipulates the Simbots on the playing field and generates data files of their movements, and a 3D graphical visualization that allows the user to see the Simbots in action. The C++ program uses a Simbot class to instantiate two Simbots which are composed of three basic components: base, optics and weapons. The graphics portion uses data files created in the main simulation and displays in 3D animation. The simulation correctly replicates the logical and physical aspects of the robot competition. Future research on the physical aspects of the component parts and the graphics package can be integrated with this foundation.

LOW-COST DIGITAL SIGNAL PROCESSOR (DSP) BASED TORPEDO COUNTERMEASURE WITH AUTONOMOUS TARGET MOTION ANALYSIS (U)

Martin L. Whitfield-Lieutenant, United States Navy

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Master of Science in Computer Science-June 1997

Advisors: Don Brutzman, Undersea Warfare Academic Group

Robert B. McGhee, Department of Computer Science

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1